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Sup Court

TRANSCRIPT OF RECORD.

SUPREME COURT OF THE UNITED STATES.

OCTOBER TERM, 1900.

No. ~~[illegible]~~ 17.

THE CARNEGIE STEEL COMPANY, LIMITED,
PETITIONER,

vs.

THE CAMBRIA IRON COMPANY.

ON WRIT OF CERTIORARI TO THE UNITED STATES CIRCUIT COURT
OF APPEALS FOR THE THIRD CIRCUIT.

PETITION FOR CERTIORARI FILED OCTOBER 18, 1899.
CERTIORARI AND RETURN FILED NOVEMBER 28, 1899.

(17,541.)

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a In the United States Circuit Court of Appeals, Third Circuit, March Term, 1899.

Among the rolls, records and judicial proceedings in the circuit court of the United States for the western district of Pennsylvania, at No. 2 May term, 1896, may be found the following words and figures, to wit:

Docket Entries.

THE CARNEGIE STEEL COMPANY, LIMITED, vs. THE CAMBRIA IRON COMPANY. } No. —.

Bill filed December 2, 1895. Same day subpœna issued, returnable first Monday of January next. 1896, Jan. 6, subpœna served on said def't company by giving a true and attested copy to C. S. Price, general manager of said Co. Mar. 87.24. 1896. April 8, answer filed. 1896, May 9th, replication filed. 1896, June 13, order that respondents close their testimony on or before Jan'y 15th, 1897, filed. And now, Jan'y 14th, 1897, on motion, the time for closing respondent's testimony is extended to Jan. 27, 1897, exclusive. 1897, Oct. 23, aff't of Coleman Sellers on motion of def't to take surrebuttal testimony filed. Also motion and order thereon filed. 1897, Nov. 19, complainant's testimony filed. 1897, Jan'y 7th, Complainant's Exhibits "General Plan Edgar Thomson Works," "Gayley Article," "Gayley Records of Mixer and
b Furnace Analysis," "Durfee Patent No. 114,277," "Certificate from British Patent Office," "Hand Sketch of Crucibles of the Whitney Cupolas," "Limited Partnership Certificate," "Cert. Copy Jones Patent," "Blue Print No. 2 Defendant's Mixer," "Edgar Thomson Mixer," "Photograph Whitney Cupolas (2)" and Complainant's Exhibit "Duquesne Mixer" filed. 1898, Jan'y 10th, Complainant's Exhibit Assignment filed. 1898, Jan. 10, defendant's testimony and Exhibits "Maryland Steel Company Discontinuance," "Holley Mill," "Deighton Capacity No. 1," "Deighton Receiving Vessel 1873," "Analysis," "Deighton's Capacity No. 2," "No. 3 Working Drawing Whitney Plant," "No. 4 Working Drawing Whitney Plant," "No. 8 Cambria Plant," "No. 9 Cambria Plant 1880 to 1881," "Graphic Record Fixed Mixer Sheets 1, 2, 3, 4," "South Chicago Reservoir," "Plan Casting 20-inch Gun," "Drawing Altoona Reservoir," "Plan Altoona Wheel Foundry," "Fixed Receiver," "Open Hearth Furnaces Nos. 1, 2, 3, 4," filed and surrebuttal evidence filed. 1898, Jan'y 11th, 12th, 13th and 14th. Case argued. *C. A. V.* 1898, Feb'y 26th. Complainants move for leave to file a disclaimer to certain parts of the specifications of letters patent in suit, and directed that the motion be filed and Tuesday, March 8th, 1898, be fixed for hearing same. 1898, Sept. 5th. Opinion of the court filed sustaining second claim of patent without costs. 1898, Sept. 20th. Decree filed adjudging com-

plainant's letters patent to be good and valid as to the second claim thereof, and defendant company to have infringed said second claim; and ordering that it be referred to H. D. Gamble, Esq., as master to ascertain the amount of the damages sustained by the said complainant by reason of such infringement, and that a writ of injunction issue according to the prayer of the bill. 1898, Oct. 14th. Injunction issued and service accepted by Jas. I. Kay, Esq., att'y for defendant. 1898, Oct. 17th. Motion to suspend injunction pending appeal filed, and notice of hearing with service
c thereon of date Oct. 14th, 1898, filed. 1898, Oct. 17th. Motion to suspend injunction argued and ordered that the injunction and all proceedings before the master be and are suspended pending the hearing and decision of the appeal at the March term, 1899, provided that if the hearing of said appeal be continued after said March term, 1899, then this suspension shall terminate unless renewed by this court upon application thereto. 1898, Oct. 17th. Petition for appeal presented and appeal allowed. 1898, Oct. 17th. Assignments of error filed. *Eo die* bond approved and filed. 1898, Oct. 18th. Citation issued returnable Nov. 17th, 1898, and same day served on Bakewell & Bakewell, Esqs., sol'rs for complainant.

1 In the Circuit Court of the United States, Western District of Pennsylvania.

THE CARNEGIE STEEL COMPANY, LIMITED, *vs.* THE CAMBRIA IRON COMPANY. } In Equity. No. 2. May Term, 1896. Patent No. 404,414.

Bill of Complaint.

(Filed Dec. 2, 1895.)

To the honorable the judges of the said court:

I. The Carnegie Steel Company Limited, doing business at Pittsburg, Pennsylvania and a citizen of said State, being a limited partnership association under the laws of said State, brings this its bill against the Cambria Iron Company, domiciled and doing business at Johnstown in Cambria county, in said State, a corporation under the laws of said State, a citizen thereof, and an inhabitant of the western district thereof:

And thereupon your orator complains and says as follows:

II. That on the 31st day of October, in the year one thousand eight hundred and eighty-eight, William R. Jones having invented, and being the true, original and first inventor of a certain new and useful improvement in methods of mixing molten pig metal not known or used before, not patented or described in any
2 printed publication in this or any foreign country before said invention thereof, not abandoned, and not in public use or on sale in the United States for more than two years prior to the date of the application for a patent, made application for letters

patent to the proper department of the Government of the United States in accordance with the then existing laws of Congress, and having duly complied in all respects with the requirements of said laws, on the fourth day of June, A. D. 1889, letters patent of the United States No. 404,414, signed, sealed and executed in due form of law, for the said invention or discovery, were issued to the said William R. Jones, whereby there was secured to him and to his heirs, executors, administrators and assigns, for the term of seventeen years from the said date of issue, the full and exclusive right of making, using and vending to others to be used, the said improvement.

III. That a description of the aforesaid improvement was given in the specification forming part of and annexed to the said letters patent. The said letters patent and specification (which, or an exemplified copy of which, your orator will produce, as your honors may direct) were duly recorded in the Patent Office. A copy of said specification is herewith filed as an exhibit, is to be taken as part hereof, and is marked Exhibit "A."

IV. That by virtue of sundry assignments, all the right, title and interest in and to said letters patent became and now is vested in your orator, as will be made more fully to appear by said assignments in court to be produced, as your honors may direct.

V. That the said patented improvements have been extensively applied to practical use under said letters patent, and are of great utility and benefit. That the public have had sufficient notice that articles made under your orator's said letters patent are patented, and all articles and apparatus made and sold thereunder
3 have been marked by fixing thereon the word patented, together with the day and year of the grant of said letters patent, in manner as required by the provisions of the act of Congress for such case made and provided. The public generally have recognized and acquiesced in the validity of said letters patent, the utility of said improvements, and your orator's exclusive title thereto; so that your orator, who owns and possesses the entire title to said letters patent, has been, and but for the infringement hereinafter complained of, would still be in undisturbed enjoyment of the exclusive privileges secured by the said letters patent and in receipt of the profits thereof.

VI. That the said defendant has well known all the facts hereinbefore set forth, and has been duly notified of the date and grant of your orator's said letters patent and of the said defendant's infringement thereof, but nevertheless has made, sold and used, and after said notice, without license of your orator, against your orator's will, and in violation of your orator's rights, now continues to make, sell and use within the western district of Pennsylvania and elsewhere a method of mixing molten pig metal, in some parts thereof substantially the same in construction and operation as in the said letters patent claimed, the exclusive right and privilege to make, sell and use which is thus by law vested in your orator; and refuses to pay to your orator any of the profits which have been made by such unlawful manufacture, sale and use, or to desist from the

further infringement of said recited letters patent; all of which acts are in violation of the exclusive rights and privileges vested in your orator by virtue of said recited letters patent, are contrary to equity and good conscience, and tend to the manifest injury of your orator in the premises.

VII. Your orator, therefore, prays:

1. That the said defendant shall, according to the best and utmost of its knowledge, remembrance, information and belief, make, to the matters and things hereinbefore stated and charged, full, true, direct and perfect answer, not, however, under oath, which is hereby waived.

2. That a writ of subpœna may issue, directed to the said defendant, The Cambria Iron Company, commanding it on a day certain therein to be named, to appear and answer unto this bill of complaint, and to abide and perform such order and decree in the premises as to this court shall seem meet and may be required by the principles of equity and good conscience.

3. That the said defendant may be decreed to account for and pay to your orator the profits or income thus unlawfully derived from the violation of your orator's rights, and that upon entering of the decree against the defendant for infringement, your honors may proceed to assess or cause to be assessed under your direction as well the defendant's said unlawful profits or income, as also in addition thereto the damages sustained by your orator by reason of defendant's said infringement, and that the court may increase the actual damages so assessed to a sum equal to three times the amount of such assessment, under the circumstances of the willful and unjust nature of said infringement.

4. That a writ of injunction may be issued from and under the seal of this court, perpetually enjoining and restraining the said defendant, its clerks, attorneys, servants, agents and workmen from any further manufacture, sale or use in any manner of said patented improvements, or any part thereof, in violation of your orator's rights; and that the infringing devices now in possession or use of the said defendant may be decreed to be destroyed or delivered to your orator for that purpose.

5. That a provisional or preliminary injunction be issued, restraining said defendant, its clerks, agents, attorneys, workmen and servants from any further manufacture, sale or use in any manner of said patented improvements, or any part thereof, pending this cause.

6. That such other and further relief may be granted and decreed to your orator as the equity of the case may require, and to your honors may seem meet.

THE CARNEGIE STEEL CO., LIMITED,
By JOHN G. A. LEISHMAN, *President.* [SEAL.]

Attest: F. T. F. LOVEJOY, *Secretary.*

W. BAKEWELL,
JAMES K. BAKEWELL,
Solicitors for Complainant.
BAKEWELL & BAKEWELL, *Of Counsel.*

UNITED STATES OF AMERICA, *Western District of Pennsylvania*, } ss:

Before me personally came F. T. F. Lovejoy, secretary of The Carnegie Steel Company Limited, the said complainant named, who being duly sworn, deposes and says that so far as the statements in the foregoing bill contained are within deponent's own knowledge, they are true, and so far as they are derived from the information of others, he verily believes them to be true; and further, that deponent verily believes the said William R. Jones to be the original, true and first inventor of the new and useful invention described in the letters patent in said bill named; and that the said complainant's title to said letters patent is as set forth in the said bill.

F. T. F. LOVEJOY.

Sworn and subscribed before me this 30th day of November, 1895.

ALBERT H. EAMES, [SEAL.]
Notary Public.

To H. D. Gamble, Esq., clerk:

Issue subpœna returnable to the first Monday of January next.

BAKEWELL & BAKEWELL,
Solicitors for Complainant.

Dec. 2, 1895.

6 *Answer.*

(Filed April 8, 1896.)

The answer of The Cambria Iron Company, defendant, to the bill of complaint of The Carnegie Steel Company, Limited, complainant, in the above-entitled suit.

This defendant, now and at all times hereafter saving and reserving unto itself all and all manner of benefit and advantage of exception which can or may be had or taken to the many errors, uncertainties, and other imperfections in said bill of complaint contained, for answer thereunto, or unto so many and such parts thereof as this defendant is advised is or are material or necessary for it to make answer unto, answering, says as follows:

1. This defendant is not informed, save by said bill of complaint, whether the said complainant, The Carnegie Steel Company, Limited, is a limited partnership association under the laws of the State of Pennsylvania and a citizen of said State as alleged in its bill of complaint, and leaves the complainant to make such proof thereof as it may be advised.

2. This defendant is informed and believes that the letters patent of the United States in said bill mentioned, No. 404,414, were granted to William R. Jones, named in said bill, on June 4th, 1889, for method of mixing molten pig metal; but this defendant denies all and singular the allegations of said bill to the effect that the said Jones was the true, original and first inventor of the alleged improvement described and claimed in said letters patent; or that

the same had not been known or used by others within the United States, or had not been patented or described in any printed publication before the alleged invention thereof by the said Jones; or that the said invention had not been abandoned, or had not been in public use or on sale in the United States for more than two years prior to the date of the application on which said patent was granted;
7 or that the said Jones duly complied in all respects with the law made and provided as to the application for and issue of said letters patent; wherefore this defendant prays that the complainant may be required to make due and legal proof, all and singular, of the allegations in that behalf in said bill of complaint contained.

3. This defendant, further answering, says that it has no knowledge, save as derived from said bill of complaint, as to the assignment of the said Jones patent sued upon unto The Carnegie Steel Company, Limited, complainant in said bill, and prays that the complainant may be required to make due proof of said alleged assignment, and of its title to the said letters patent; but this defendant denies that the complainant thereby has or now possesses any such exclusive right as that alleged in said bill of complaint to the alleged invention set forth in said Jones patent, for the reason among others, that the said recited letters patent is invalid and that the said William R. Jones was not the true, original and first inventor of the alleged invention set forth therein, but the same or material and substantial parts thereof were publicly known and used, and described in prior patents and in prior printed publications, and were invented by others prior to the said alleged invention of the said William R. Jones.

4. This defendant, further answering, denies the allegations of the said bill of complaint to the effect that the said alleged patented improvements have been extensively applied to practical use; or are of great utility and benefit; or that the public generally has recognized and acquiesced in the validity of the said letters patent or the utility of the said improvements and the exclusive title of the complainant thereto. And this defendant further specifically denies that the word "patented" together with the day and year of the grant of the letters patent have been applied to the apparatus made for practicing the said invention or that this defendant
8 has ever been notified of any claim to exclusive right under the said letters patent by the said complainant.

5. This defendant, further answering, says that the said letters patent is null and void for the reason, among others, that the specification or description attached to the same is not in such full, clear, concise and exact terms as to have enabled any person skilled in the art to which the alleged invention relates, to practice the alleged invention; that the specification did not distinguish between the prior state of the art and the alleged invention claimed in the said letters patent; and that the principle or nature of the said alleged invention is not sufficiently explained to distinguish it from other and prior inventions.

6. This defendant, further answering, denies that it has infringed

upon or in any way violated any valid exclusive rights under the said letters patent No. 404,414; but this defendant admits that at its works in Johnstown, Cambria Co., Pa., and within said western district of Pennsylvania, it has employed for many years prior to the grant of the said letters patent, and since that time, ladles or receivers into which molten metal from two or more furnaces was introduced from time to time, and from which the charge from the converter was drawn from time to time as required, it having been the practice of this defendant to employ such apparatus and to practice such way of making Bessemer steel for 25 years or more.

7. This defendant, further answering, says that the said letters patent No. 404,414, does not describe anything which, in view of the state of the art, both in metal working and in other arts, at or before the date of the said alleged invention by the said Jones, constituted a patentable invention under the laws of the United States; wherefore the said letters patent are null and void.

8. This defendant further answering on information and
9 belief, says that the said letters patent No. 404,414, mentioned in the said bill of complaint is null and void, and the said complainant is not entitled to the relief prayed for thereunder or to any relief against this defendant, for the reason among others, that the said alleged invention or discovery in the said letters patent mentioned, described or claimed, or the material and substantial part or parts thereof, had been prior to the alleged invention or discovery thereof by the said William R. Jones made known, mentioned, described, or claimed in divers patents or printed publications as follows, to wit:

In the following letters patent of the United States: No. 33446 to John W. Nystrom, Oct. 8, 1861, for improvements in furnaces for the manufacture of iron and steel; No. 51398 to Henry Bessemer, Dec. 5, 1865, for making Bessemer steel; No. 94306 to Wm. Griffith, Jr., Aug. 31, 1869, for iron furnaces; No. 108,375 to John W. Middleton, Oct. 18, 1870, for producing castings direct from the blast furnace; No. 118,597 to Z. S. Durfee, Aug. 27, 1871, for method of refining cast iron and making castings; No. 122,312 to Z. S. Durfee, Jan. 2, 1872, for manufacture of iron and steel; No. 238,110 to Wm. Hainsworth, Feb. 22, 1881, for Bessemer plant; No. 284,005 to Wm. Hainsworth, Aug. 28, 1883, for Bessemer plant; No. 298,426 to John A. Stearns, May 13, 1884, for manufacture of metals direct from the ore; No. 315,587 to James P. Witherow, April 14, 1885, for apparatus for the manufacture of iron and steel, and No. 327,425 to James P. Witherow, Sept. 29, 1885, for steel plant.

In the following letters patent of Great Britain: No. 13490 of 1851 to Alexander Alliott for cleaning, dyeing and drying machinery; No. 1384 of 1855 to Henry Bessemer for manufacture of cast steel and mixtures of steel and cast iron; No. 44 of 1856 to Henry Bessemer for the manufacture of iron and steel; No. 2061 of 1856 to John L. Tabberner for smelting ores; No. 2870 of 1856 to Joseph Deeley for furnaces for smelting and melting; No.
10 16 of 1864 to William Balk for furnaces applicable in the smelting of ores and the melting of metals; No. 2940 of

1866 to Nicholas Kornshunoff for manufacture and casting of malleable iron and steel, and furnace and apparatus employed in said manufacture; No. 859 of 1866 to Clinton E. Brooman for processes of transforming scraps of steel, etc., into ingots of cast iron; No. 688 of 1868 to John Gjers for manufacture of cast steel and homogeneous iron, and in furnaces applicable thereto; No. 566 of 1869 to Henry Bessemer for the construction and arrangement of machinery, apparatus and buildings employed in and for the manufacture or production of cast steel and malleable steel from pig or other carburet of iron; No. 2988 of 1869 to Charles Wm. Siemens for smelting iron or steel and apparatus and furnaces employed in connection therewith; No. 594 of 1870 to Charles Wm. Siemens for improvements in treating iron ores and processes and apparatuses for the production of cast steel where said ores are employed; No. 685 of 1872 to Charles D. Abel for manufacture of Bessemer steel and iron, and in production of iron castings, and in apparatus therefor; No. 1063 of 1872 to Carl W. Zenger for purifying iron, copper and zinc; No. 3672 of 1873 to William Deighton for arrangement and mode of working of apparatus for the manufacture of Bessemer steel; No. 3754 of 1873 to Edwin Pettitt for smelting or reducing furnaces, and in the manufacture of iron; No. 1858 of 1874 to John H. Johnson for manufacture of iron and steel and apparatus employed therefor; No. 3840 of 1874 to Samuel R. Smyth and Joseph Simpson for manufacture of iron and steel; No. 314 of 1875 to James Kennedy and Charles Wigg for the construction of furnaces; No. 2382 of 1883 to Alexander Stewart for cupola and blast furnaces and apparatus employed in the manufacture of iron and steel and the smelting of metals; and No. 8277 of 1887 to William Jukes for the manufacture of steel and apparatus connected therewith, sealed Feb. 3, 1888.

11 In the following French patents: No. 78731, to Higonnet, Nov. 29, 1867, for cupola of small dimensions with a reservoir for accommodating the cast iron for the casting of large pieces; No. 77253, to Société Anonyme des Fonderies et Forges de Terre Noire, Aug. 1, 1867, second series, vol. 101, Fer et Acier, page 27, plate 6.

And in the following printed publications: The several English letters patent, respectfully above referred to, which said letters patent were published at London, England, in the year of their date, or the following year, as follows, to wit: Nos. 13490 of 1851, published 1852; No. 1384 of 1856, published 1863; No. 44 of 1856, published 1856; No. 2061 of 1856, published 1857; No. 2870 of 1856, published 1857; No. 16 of 1864, published 1864; No. 2940 of 1866, published 1869; No. 859 of 1866, published 1867; No. 688 of 1868, published 1868; No. 566 of 1869, published 1869; No. 2988 of 1869, published 1875; No. 594 of 1870, published 1871; No. 685 of 1872, published 1872; No. 1063 of 1872, published 1872; No. 3672 of 1873, published 1874; No. 3754 of 1873, published 1874; No. 1858 of 1874, published 1874; No. 3840 of 1874, published 1886; No. 314 of 1875, published 1875; No. 2382 of 1883, published 1884 and No. 8277 of 1887, published 1888.

In the following publications:

"The Founding of Metals," by Edward Kirk, published in Sharon, Pa., in 1879, and on pages 19 and 20 thereof.

"The Founding of Metals," by Kirk, published in New York, 1881, and on pages 19 and 20 thereof.

"Overman's Molders' and Founders' Guide," published in Philadelphia, Pa., in 1880, and on page 209 thereof.

"Steel, its History, Manufacture, Properties and Uses," by J. S. Jeans, published in London, England, 1880, and on pages 421–'2; also on pages 433 to 436 with the accompanying cuts.

12 "A Practical Treatise on Casting and Founding," by N. E. Spretson, published in London, England, 1884, and on pages 55 to 56; also on pages 276 to 278; also on pages 374 to 378; also the accompanying cuts and especially plate 79.

"Journal of the Iron and Steel Institute" for the year 1871, published in London, England, in 1871 or 1872, and on pages 413 and 414 thereof.

"Journal of the Iron and Steel Institute" for the year 1874, published in London, England, 1874 or 1875, and on pages 354 to 364 thereof; also on page 373 thereof.

"Journal of the Iron and Steel Institute" for the year 1875, published in London, England, 1875 or 1876, and on pages 25, 127, 194 to 195, 200 *et seq.*, being a discussion entitled "The Bessemer foundry;" also on page 344.

"Journal of the Iron and Steel Institute" for the year 1876, published in London, England, 1876 or 1877, on pages 12 to 25 thereof.

"Journal of the Iron and Steel Institute" for the year 1876, published in London, England, 1876 or 1877, on pages 420 to 427, being a discussion under date of Thursday, 21st September, 1876.

"Journal of the Iron and Steel Institute" for the year 1878, published in London, England, 1878 or 1879, pages 122–128, being a discussion on Bessemer steel.

"Engineering" for Feb. 14, 1873, published in London, England, 1873, vol. 15, pages 113 to 114.

"Engineering," vol. 18, page 310, issue of Sept. 23, 1874, published in London, England, 1874, article entitled "The Bessemer process," by Z. S. Durfee.

"Engineering" for Sept. 29, 1876, published in London, England, vol. 22, pages 272 and 273.

"Engineering" for Nov., 1876, published in London, England, 1876, vol. 22, pages 404 and 405.

13 "Engineering" for March 9, 1877, published in London, England, 1877, vol. 23, pages 182–184.

"Engineering" for May 11, 1877, published in London, England, 1877, vol. 23, on page 357 thereof, being an article referring to the Altoona shops, together with the accompanying cut referred to in said article.

"Engineering" for April 19, 1878, published in London, England, 1878, vol. 25, page 295.

"Engineering" for July 30, 1880, published in London, England,

1880, vol. 30, pages 95–97, article entitled "Barrow hematite iron and steel works."

"Engineering" published in London, England, 1881, vol. 32, pages 482 to 484 inclusive.

"Engineering" published in London, England, 1884, vol. 38, pages 119 to 122 inclusive; also page 149 and page 406.

"The Engineer," published in London, England, in 1868, vol. 25, pages 268–'9.

"The Engineer," published in London, England, vol. 35, page 361.

"Stahl und Eisen," published in Dusseldorf, Germany, 1885, vol. 5, page 26, plate 3.

"Bericht Uber die Fortschritte der Eisenhuetten-Technik im Jahre 1878," by Anton Ritter von Kerpely, published in Leipzig, Germany, 1880, pages 272–'3.

"Berg und Huetten Maennische Zeitung," edited by Bruno Kerl and Freidrich Wimmer; published by Arthur Felix, Leipzig, Germany, 1864, vol. 23, pages 80–81.

"Berg und Huetten Maennische Zeitung," edited by Bruno Kerl and Freidrich Wimmer; published by Arthur Felix, Leipzig, Germany, Oct. 16, 1865, vol. 24, page 360.

A publication published in London, England, in the year 1871, as a provisional specification of English patent No. 2415, dated Sept. 14, 1871, to Brierly Denham Healey for casting pits and cranes therefor.

14 "Moulder's and Founder's Pocket Guide," published by Fred. Overman in Philadelphia, Pa., in the year 1870, pages 190–209 thereof.

"Die Metallurgie," by C. Stoetzel, vol. 1, published in Braunschweig, 1860, article 157, pages 332–'3.

"A Work on Metallurgy," by Wm. Crookes and Ernest Rohrig, published in New York by John Wiley and Sons in 1869, pages 542 and 543 thereof.

In addition to the foregoing patents and printed publications, this defendant upon information and belief says that divers other patents and printed publications had made known, mentioned or described or claimed the said alleged invention or discovery, which said other patents or printed publications, when the same shall have been more fully ascertained, this defendant craves leave to set forth by way of supplement, amendment, or addition to this answer with like effect as if the same were here mentioned or claimed.

9. This defendant further answering upon information and belief, says that the said letters patent No. 404,414, mentioned in said bill of complaint are null and void, and that the said complainant is not entitled to the relief prayed for therein, or to any relief against this defendant, for the reason among others, that the said alleged invention or discovery in said letters patent mentioned, described or claimed, or the material or substantial part or parts thereof, were known to and used by divers persons within the United States, and that the following persons respectively are among those who used the same or knew of such use, at the following-named places respectively, to wit:

At the foundry of James Marshall & Co., Pittsburgh, Pa., and such prior use was known to William Yagle, now residing in Pittsburgh, and others.

At the Fort Pitt foundry in Pittsburg aforesaid, then operated by Knap, Wade and Co., or Knap, Rudd and Co., such prior use was known to William Metcalf and Robert Sleeth, both now residing in Pittsburgh, and others.

At the foundry of Totten and Co., in said Pittsburgh, and such prior use was known to R. C. Totten, now residing at Sewickley, Allegheny county, Pa., Thomas Rafferty, now residing in Pittsburgh aforesaid, and others.

At the foundry of Seamen, Sleeth and Black, in Pittsburgh, Pa., and such prior use was known to Robert Sleeth, now residing in Pittsburgh, and others.

At the works of Mitchell, Stevenson and Co., in Pittsburgh, Pa., and such prior use was known to William Graham, now residing in Allegheny City, Pa., and John C. Reed, now residing in Millvale, Allegheny county, Pa., and others.

At the works of the Detroit Stove Co., in Detroit, Mich., and such prior use was known to certain parties whose names this defendant prays leave to plead as an addition to this answer.

At the Peninsular stove works at Detroit, Mich., and such prior use was known to certain parties whose names this defendant prays leave to plead as an addition to this answer.

At the works of A. Whitney and Sons, in Philadelphia, Pa., and such prior use was known to John R. Whitney, now residing at Bryn Mawr, Pa., and Adam J. Frederick, now residing at Camden, N. J., and others.

At the works of the Pennsylvania Steel Co. at Steelton, Pa., and such prior use was known to Harry M. Campbell, now residing at Steelton, Pa., Jacob B. Martin, now residing at Steelton, Pa., and others.

At the works of the defendant, The Cambria Iron Company, in Johnstown, Pa., and such prior use was known to Homer A. McGravey, F. P. Hershey, Joseph Morgan, Jr., and John W. Cabot, all now residing at Johnstown, Pa., and others.

16 At the works of the Lackawanna Iron and Steel Co., at Scranton, Pa., and such prior use was known to T. G. Wolf, now residing at Scranton, Pa., George F. Barnard, now residing at Scranton, Pa., and others.

At the works of the Taylor Iron and Steel Co., at High Bridge, N. J., and such prior use was known to William J. Taylor, now residing at said High Bridge, and others.

At the works of the Illinois Steel Co. at South Chicago, Ill., and such prior use was known to R. Forsyth, now residing in Chicago, Ill., and others.

At the works of said Illinois Steel Co., at Joliet, Ill., and such prior use was known to R. Forsyth aforesaid, and others.

At the Edgar Thomson steel works, and such prior use was known to John Rinard, now residing at Braddock, Allegheny county, Pa., Joseph Morgan, Jr., aforesaid, and others.

At the wheel foundry of the Pennsylvania Railroad Compan Altoona, Pa., and such prior use was known to E. McLain, D Spielman and Daniel Osbaugh, all now residing in Altoona af said, and others.

In addition to the prior use at the above-named places and by foregoing persons, this defendant upon information and belief s that the said alleged invention was known and used at other pla within the United States and that such prior uses were known divers others persons whose names and residences and the plac such use when the same shall be more fully ascertained, this fendant respectfully craves leave to set forth by way of supplem amendment, or addition to this answer, with like effect as if same were here mentioned and contained.

10. This defendant, further answering on information and bel says that the said William R. Jones actually abandoned
17 said alleged invention set forth in the said letters patent 404,414, prior to making any application for letters pat therefor.

11. This defendant, further answering on information and bel says that the alleged invention was in public use within the Uni States for more than two years before the said William R. Jo made any application for letters patent therefor, at the followi places, to wit: At the several places named in paragraph 9 of t answer, and also, in addition thereto, at the Edgar Thompson st works, which works are now owned by the above-named compla ant and that such prior use was known to said William R. Jon and John Rinard, Joseph Morgan, Jr., and others, wherefore s letters patent are null and void.

12. This defendant, further answering, says that the said Willi R. Jones, the patentee named in said letters patent, No. 404,414, w not an original inventor of the improvements described and claim in the said letters patent, for the reason, among others, that t same was described in a certain report made by A. L. Holley to t Bessemer Steel Co., Limited, to wit, a report entitled "Report to t Bessemer Steel Co., Limited, No. 1, 1880," being in connection wi the West Cumberland works; which report was furnished to t several manufacturers of Bessemer steel within the United Stat and among others to the Edgar Thomson steel works, then operate by Carnegie Brothers & Co., Limited, of which works the sa William R. Jones was manager at that time, the year 1880, a which report was examined by the said William R. Jones, whe fore the said letters patent are null and void.

All of which defenses and statements this defendant is ready aver, maintain and prove as this honorable court shall direct, a it humbly prays to be hence dismissed with its reasonable cost this behalf most wrongfully sustained.

CAMBRIA IRON COMPANY,
By POWELL STACKHOUSE, *President.*

KAY & TOTTEN,
Solicitors for Defendant.
JAMES I. KAY, *Of Counsel.*

18 STATE OF PENNSYLVANIA, } ss:
County of Philadelphia, }

Powell Stackhouse, being duly sworn, deposes and says that he is the president of the said Cambria Iron Company, the above-named defendant, that he has read or heard the foregoing answer of said company by him signed as president of said company, and knows the contents thereof; that the facts set forth therein so far as they are within his own knowledge are true, and so far as the same are derived from information obtained from others he verily believes them to be true.

POWELL STACKHOUSE.

Sworn to and subscribed before me this 6th day of April, 1896.

RICHMOND M. DUKES, JR.,
Notary Public.

[SEAL.]

Replication.

(Filed May 9, 1896.)

The replication of the complainant, The Carnegie Steel Company, Limited, to the answer of the defendant, The Cambria Iron Company.

This repliant, saving and reserving to itself all and all manner of advantage of exception to the manifold insufficiencies of the said answer, for replication thereto, says that it will aver and prove its said bill to be true, certain and sufficient in law to be answered unto, and that the said answer of the said defendant is uncertain, insufficient and untrue; without this, that any other matter or thing whatsoever in the said answer contained, material or effectual in the law to be replied unto, confessed and avoided, traversed and denied, is true; all of which matters and things this repliant is and will be ready to aver and prove, as this honorable court shall direct, and humbly prays, as in and by its said bill it has already prayed.

BAKEWELL & BAKEWELL,
JAMES K. BAKEWELL,
Solicitors for Complainants.

19 Circuit Court of the United States, District of Maryland.

THE CARNEGIE STEEL CO., LTD., *vs.* MARYLAND STEEL COMPANY and FREDERICK W. WOOD, Receiver.	In Equity. Patent No. 404,414.

Bill.

To the honorable the judges of said court:

The Carnegie Steel Company, Limited, a limited association organized and existing under the provisions of an act of the legislature of the State of Pennsylvania, approved June 2d, 1874, entitled

"An act authorizing the formation of partnership associations, in which the capital subscribed shall alone be responsible for the debts of the association, except under certain circumstances," and its supplements, domiciled in the county of Allegheny, in the western district of said State of Pennsylvania, a citizen of said State and authorized by the laws of said State to sue and to be sued in its own name, brings this bill against the Maryland Steel Company, a corporation organized and existing under the laws of the State of Maryland, a citizen of said State of Maryland, domiciled at Sparrows Point in said Maryland, and Frederick W. Wood, of said Sparrows Point, and a citizen of said State of Maryland, who, by order of the circuit court No. 2 of Baltimore city, on —— —, 1892, was appointed receiver of said Maryland Steel Company, and is now receiver thereof, having taken possession of its property and business in pursuance of his appointment; this bill being filed by leave of said circuit court No. 2 of Baltimore.

20 And thereupon your orator complains and says as follows:

I. That on the 31st day of October, 1888, one William R. Jones, having invented and being the true, original and first inventor of a certain new and useful improvement in methods of mixing molten pig metal, not known or used before, not patented or described in any printed publication in this or any foreign country before said invention thereof, not abandoned and not in public use or on sale in the United States for more than two years prior to the date of the application for a patent, made application for letters patent to the proper department of the Government of the United States in accordance with the then existing laws of Congress, and having duly complied in all respects with the requirements of said laws, on the 4th day of June, 1889, letters patent of the United States No. 404,414, signed, sealed and executed in due form of law, for the said invention or discovery, were issued to him the said William R. Jones, whereby there was secured to him and to his heirs, executors, administrators and assigns for the term of seventeen years from the said date of issue, the full and exclusive right of making, using and vending to others to be used, the said improvement.

II. That a description of the aforesaid improvement was given in the specification forming part of and annexed to the aforesaid letters patent. The said letters patent and specification (which, or an exemplified copy of which your orator will produce, as your honors may direct) were duly recorded in the Patent Office. A copy of said specification is herewith filed as an exhibit.

III. That thereafter, by certain deeds of assignment, duly executed and recorded in the United States Patent Office, the entire and exclusive title and interest in and to said letters patent, and all the interest of the said William R. Jones, therein, together with all claims for damages and profits arising from infringement of

21 said letters patent since the date thereof, and the right to sue for the same, were assigned to and became vested in your orator; as by said deeds of assignment or duly authenticated copies

thereof, here in court to be produced, as your honors may direct, will fully appear.

IV. Your orator, The Carnegie Steel Company, Limited, was formerly named and styled Carnegie Brothers and Company, Limited, it having in pursuance of and in accordance with the laws of the State of Pennsylvania, by declaration duly recorded on the 30th day of June, 1892, in the office of the recorder of deeds in and for the county of Allegheny in said State of Pennsylvania, changed its name from Carnegie Brothers and Company, Limited, to its present name, the Carnegie Steel Company, Limited, as by said declaration, or a duly authenticated copy thereof, here in court to be produced, as your honors may direct, will more fully appear.

V. That the said patented improvements have been extensively applied to practical use under said letters patent, and are of great utility and benefit. The public generally have recognized and acquiesced in the validity of said letters patent, the utility of said improvements, and your orator's exclusive title thereto; so that your orator, who owns and possesses the entire title to said letters patent, has been, and but for the infringement hereinafter complained of, would still be in undisturbed enjoyment of the exclusive privileges secured by the said letters patent, and in receipt of the profits thereof.

VI. That the said defendant, Frederick W. Wood, as receiver of said Maryland Steel Company, well knowing all the facts hereinbefore set forth, has been and is now using, and that prior to the date of his appointment as receiver and after the date of said letters patent and the dates of the assignment thereof to your orator, the said Maryland Steel Company used and is now using meth-
22 ods of mixing molten pig metal, in some parts thereof substantially the same as in the said letters patent mentioned, the exclusive right and privilege to make, use, and sell which, is thus by law vested in your orator. And so it is that the defendants, without license of your orator, against its will, and in violation of its rights, have used and intend and threaten to continue still to use the said improvements within the district of Maryland, and refuse to pay to your orator any of the profits which have been made by such unlawful use, or to desist from the further infringement of said recited letters patent; all of which acts are in violation of the exclusive rights and privileges vested in your orator by virtue of said recited letters patent, are contrary to equity and good conscience, and tend to the manifest injury of your orator in the premises.

VII. Your orator therefore prays:

1. That said defendants shall, according to the best and utmost of their knowledge, remembrance, information and belief, make to the matters and things hereinbefore stated and charged, full, true, direct, and perfect answer, not, however, under oath, which is hereby waived.

2. That a writ of subpœna may issue, directed to the said defendants, Maryland Steel Company and Frederick W. Wood, receiver, commanding them on a day certain therein to be named, to appear and answer unto this bill of complaint, and to abide and perform such order and decree in the premises as to this court shall seem

meet and may be required by the principles of equity and good conscience.

3. That the said defendants may be decreed to account for and pay over the profits or income thus unlawfully derived from the violation of your orator's rights as aforesaid, and that upon entering of the decree against the defendants for infringement, your honors may proceed to assess or cause to be assessed under your direction as well as the said defendants, unlawful profits or income, as also in addition thereto the damages sustained by your
23 orator by reason of the defendants' said infringement, and that the court may increase the actual damages so assessed to a sum equal to three times the amount of such assessment, under the circumstances of the willful and unjust nature of said infringement.

4. That a writ of injunction may be issued from and under the seal of this court, perpetually enjoining and restraining the said defendants, their clerks, attorneys, servants, agents and workmen, from any further use in any manner of said patented improvements, or any part thereof, in violation of your orator's rights.

5. That a provisional or preliminary injunction be issued, restraining said defendants, their clerks, agents, attorneys, workmen and servants, from any further use in any manner of said patented improvements, or any part thereof, pending this cause.

6. That such other and further relief may be granted and decreed to your orator as the equity of the case may require, and to your honors may seem meet.

THE CARNEGIE STEEL CO., LTD.
H. C. FRICK, *Chairman.*

W. BAKEWELL & SONS,
Solicitors for Complainant.

Oath.

UNITED STATES OF AMERICA, }
Western District of Pennsylvania, } ss:

Before me personally came H. C. Frick, chairman of The Carnegie Steel Company, Limited, the said complainant named, who, being duly sworn, deposes and says that so far as the statements in the foregoing bill contained are within deponent's own knowledge they are true, and so far as they are derived from the information of others, he verily believes them to be true. And further, that deponent verily believes the said William R. Jones to have been the original, true and first inventor of the new and useful in-
24 vention described in the letters patent in said bill named; and that the said complainant's title to said letters patent is as set forth in the said bill.

H. C. FRICK.

Sworn and subscribed before me this 16th day of October, 1893.
[SEAL.] GIBSON D. PACKER,
Notary Public.

Circuit Court of the United States, District of Maryland.

THE CARNEGIE STEEL CO., LTD.,
vs.
MARYLAND STEEL COMPANY OF BALTIMORE County and Frederick W. Wood, Receiver.

In Equity. Patent No. 404,414.

Answer.

The defendants, The Maryland Steel Company of Baltimore County, and Frederick W. Wood, receiver, for answer to the bill of complaint of the complainant or so much thereof as they are advised it is necessary to answer, answering say:

The defendants admit the existence of said defendant corporation in the form and manner alleged in said bill, and that the defendant Frederick W. Wood was appointed and now is the receiver thereof.

The defendant denies on information and belief that Wm. R. Jones was the original, true or first inventor of the alleged new and useful improvement in methods of mixing molten pig metal, as described and claimed in letters patent of the United States No. 404,414, mentioned in said bill.

And the defendant also says on information and belief that the said method was not an invention and was not of a patentable nature at the time it was produced by the said Wm. R. Jones.

And defendant further says on information and belief that the said method described and claimed in letters patent 404,414 was not novel at the date of the application for or issuance of said patent, and that methods substantially identical therewith in character were previously known and described in the following letters patent of Great Britain: No. 3672, dated November 11, 1873, to Wm. Deighton, for arrangement and mode of working apparatus for the manufacture of Bessemer steel, sealed January 20, 1874; No. 8277, dated June 9, 1887, to William Jukes, for improvements in the manufacture of steel; No. 688, dated January 28, 1868, to John Rijers for improvements in the manufacture of cast steel and homogen-ous iron, and in furnaces applicable thereto; No. 1384, dated June 18, 1855, to Henry Bessemer, for improvements in the manufacture of cast steel and mixtures of steel and cast iron, sealed December 18, 1855; No. 314, dated January 27, 1875, to James Kennedy and Charles Wigg, for improvements in the construction of furnaces; No. 1858, dated May 28, 1874, to John Henry Johnson, for improvements in the manufacture of iron and steel and in an apparatus employed therefor; No. 566, dated February 23, 1869, to Henry Bessemer, for improvements in the construction and arrangement of machinery, apparatus, and buildings employed in or for the manufacture or production of cast steel and malleable steel from pig or other carburet of iron; No. 594, dated February 28, 1870, to Chas. W. Siemens, for improvement in treating iron ores and in processes and apparatus for the production of cast steel where said ores are employed, sealed May 3, 1870; No. 44, dated

January 14, 1856, to Henry Bessemer, for improvements in
26 the manufacture of iron and steel, sealed June 24, 1856; No. 2382, dated March 10, 1883, to Alex. Stewart Bradford, for improvements in cupola and blast furnaces and in apparatus employed in the manufacture of iron and steel and the smelting of metals; No. 2870, dated December 3, 1856, to Joseph Deeley, for improvements in furnaces for smelting and melting, sealed May 29, 1857; No. 16, dated January 2, 1864, to William Balk, for improvements in furnaces, applicable in the smelting of ores and in the melting of metals, sealed June 24, 1864; No. 2940, dated November 10, 1866, to Nicholas Korshunoff, for improvements in the manufacture and casting of malleable iron and steel and in furnaces and apparatus employed in the said manufacture, sealed April 16, 1867; No. 3754, dated November 19, 1873, to Edwin Pettitt, for smelting or reducing furnaces and manufacture of iron, sealed May 15, 1874; No. 2988, dated October 14, 1869, to Chas. Wm. Siemens, for smelting iron and steel and in apparatus and furnaces employed in connection therewith, sealed December 7, 1870, the same being also described in a printed publication under the above-named title, as the provisional specification printed by Geo. E. Eyre and Wm. Spottiswoode, of 25 Southampton buildings, London, England, in 1869 and 1870; No. 2061, dated September 4, 1856, to John L. Tabberner, for improvements in smelting ores; No. 13490, dated February 3, 1851, to Alexander Alliott; No. 685, dated March 6, 1872, to Chas. Denton Abel; No. 1063, dated April 10, 1872, to Karl Wenzel Zenger; No. 3840, dated November 7, 1874, to Samuel Richard Smyth and Joseph Sampson; No. 859, to Clinton Edgcumbe Brooman, dated March 23, 1866, "a new or improved process for transforming scraps of steel, etc., into ingots of cast steel," sealed September 22, 1866.

The defendant further says on information and belief that the process described and claimed in letters patent 404,414, men-
27 tioned in the said bill of complaint, was previously known and described in the following patents of the United States: No. 238,110 to Wm. Hainesworth, dated February 22, 1881, for Bessemer plant and apparatus; No. 51398, to Henry Bessemer, dated December 5, 1865, for making Bessemer steel; No. 94306, to Wm. Griffith, Jr., dated August 31, 1869, for an iron furnace; No. 315,587, to Chas. P. Witherow, dated April 14, 1885, for apparatus for the manufacture of iron and steel; No. 33446, to John W. Nystrom, dated October 8, 1861, for improvement in furnaces for the manufacture of iron and steel; No. 284,005, to Wm. Hainsworth, dated August 28, 1883, for Bessemer plant; No. 284,425, to Jas. P. Witherow, dated September 29, 1885, for steel-plant appliances; No. 298,426, to John A. Stearns, dated May 13, 1884, for the manufacture of metals direct from the ore; No. 108,375, antedated October 8, 1870, to John W. Middleton; No. 118,597, dated August 27, 1871, to Z. S. Durfee, for method of refining cast iron and making castings; No. 122,312, dated January 2, 1872, antedated December 16, 1871, to Z. S. Durfee, for manufacture of iron and steel.

The defendant further answering says that the process described

and claimed in the said patent No. 404,414, mentioned in said bill of complaint, was previously known and described in printed publications as follows:

A publication by George E. Eyre and Wm. Spottiswoode, issued under and by authority of the patent office of Great Britain, in the year 1871, as a provisional specification No. 2415, dated September 14, 1871, to Brierly Denham Healey, Swansea, England, for improvements in casting pits and cranes therefor.

A publication entitled "Molders' and Founders' Pocket Guide," by Fred. Overman, published by Moss & Co., of Philadelphia, Pa., in the year 1870, pages 190 and 209.

28 Also in a publication entitled "Metallurgie," by C. Stoetzel, Friedr. Vieweg, Braunschweig, 1863–1886, S. 332.

Also in a publication by Wm. Crooke and Ernst Rohrig on metallurgie, John Wiley and Sons, New York, 1869, pages 542 and 543.

Also in a publication entitled "The Journal of the Iron and Steel Institute," published by E. & F. N. Spon, London, England, to be found in the library of the Patent Office of the United States at Washington, D. C., and there received September 25, 1880, vol. 8, between line 21, page 24, and line 3, page 25.

And defendant further alleges on information and belief that a process substantially identical with that described and claimed in said letters patent No. 404,414 was previously known and used in the United States at the places and by the persons following:

By the Cambria Iron Company and its workmen, whose names are at this time unknown, at its works at Johnstown, Pennsylvania, which use was known to Jacob Fritz, then a resident of Johnstown, to Simon Collin, then a resident of Johnstown, Penn., and to Joseph Morgan, Jr., then and now a resident of Johnstown, Penna.

Also by Rob't W. Hunt at Troy, N. Y., and by the Albany & Rensselaer Iron and Steel Company at Troy, N. Y., which use was known to and participated in by Robert W. Hunt, then a resident of said Troy and now residing at Chicago, Illinois.

Also by the Lackawanna Iron and Steel Company, and its workman whose names are at this time unknown, at its works at Scranton, Pa., which works were formerly operated during the use of said process by the Lackawanna Iron and Coal Company, said use being known among others to Carl W. McKinney, a resident of Scranton, Pa.

29 And defendant further answering says, that a process substantially identical with that described and claimed in the letters patent No. 404,414, named in said bill of complaint, was described in a printed publication entitled "Journal of the Steel and Iron Institute," published in the year 1874, in proceedings of Thursday, September 3, 1874, pages 359 to 362 inclusive; also in the same publication, proceedings of March 29, 1876, page 20; also page 24 of the same publication; also in the same publication, proceedings of March 28, 1878, pages 123 to 124.

Also in a printed publication known as the London Engineering, published in London, England, edited by Wm. H. Maw and James

Dredge, dated August 20, 1875, page 174, a copy of this publication being found in the library of the United States Patent Office at Washington, D. C.

The defendant further answering says, on information and belief, that the said Wm. R. Jones actually abandoned his said alleged invention before he made any application for letters patent thereon.

And the defendant further answering says, on information and belief, that the said alleged invention was in public use in the United States more than two years before the said Wm. R. Jones made any application for letters patent thereon.

And the defendant further answering says that it has no knowledge whether the said Wm. R. Jones executed and delivered any instrument of assignment to the Carnegie Steel Company, Ltd., purporting to convey the entire right, title and interest in said alleged invention and letters patent, and demands that the complainant shall make strict proof thereof.

And the defendant denies on information and belief, that
30 it ever used, or caused to be used, any process covered by the said letters patent No. 404,414, and likewise denies that it ever derived any profit from any such use, and likewise denies that the complainant ever incurred any damage on account of any such alleged transaction, committed or caused to be committed by the defendant.

All of which defenses and statements this defendant is ready to aver, maintain and prove, as this honorable court shall direct; and it prays hence to be dismissed with its costs in this behalf sustained.

In witness whereof, the said defendant The Maryland Steel Company has hereunto affixed its seal and caused the same to be attested by its secretary.

Attest:

[SEAL.] EDMUND N. SMITH, *Secretary.*
FREDERICK W. WOOD, *Receiver.*

J. H. PRESTON,
PHILIP T. DODGE, *Of Counsel.*

STATE OF PENNSYLVANIA, }
County of Philadelphia, } ss:

On this 21st day of December, 1893, before me personally appeared Edmund N. Smith, secretary of the Maryland Steel Company, and made oath that he has read the foregoing answer and knows the contents thereof, and that the same is true to his own knowledge, except as to the matters which are therein admitted or stated to be based on information and belief, and that as to those matters he believes them to be true.

EDMUND N. SMITH.

Sworn and subscribed before me the day and year aforesaid.

[SEAL.] JOHN G. LAMB,
Notary Public.

31 UNITED STATES OF AMERICA, } ss:
District of Maryland, }

I, James W. Chew, clerk of the circuit court of the United States for the district of Maryland, do certify that the foregoing is a true copy of the answer filed in the above-entitled cause on December 22, 1893.

In testimony whereof I hereunto set my hand and affix the seal of the said circuit court this 27th day of December, A. D. 1893.

[SEAL.] JAS. W. CHEW, *Clerk.*

Complainant's Testimony.

Depositions of witnesses and other evidence on behalf of complainant in the above-entitled cause, taken under the 67th rule in equity as amended, and by agreement of counsel, at the office of Bakewell & Bakewell, No. 1125 Carnegie building, Pittsburg, Pa., commencing on Thursday, May 20, 1896, before G. I. Holdship, notary public and special examiner by agreement of counsel.

Present: Mr. Wm. Bakewell and Mr. J. K. Bakewell for complainant and Mr. James I. Kay, for defendant.

Stipulation.

And now, May 20th, 1896, it is agreed between counsel for the parties hereto, that any notary public, or other officer duly authorized to administer oaths may act as special examiner, for either complainant or defendant in the above case, with the same effect as if duly appointed by the court.

It is hereby stipulated that uncertified Patent Office copies of United States letters patent, and uncertified Blue Book copies of English letters patent, may be offered in evidence in this cause, with the same force and effect as if the same were duly certified. The actual date of the English patents to be taken as the date of

32 patenting, unless the question is raised by notice from one party to the other, either party having the right to correct any errors which may appear in such printed copies or Blue Book copies.

It is hereby stipulated also by counsel for the respective parties, that Harriet Jones, assignee, as executrix, under the will of William R. Jones, deceased, of letters patent No. 404,414, to Carnegie Brothers & Co., Limited, was duly appointed executrix under said will, and was authorized thereunder to make an assignment of said letters patent to the said Carnegie Brothers & Company, Limited.

BAKEWELL & BAKEWELL,
For Complainant.
JAMES I. KAY, *For Defendant.*

Exhibits Offered.

Counsel for complainant hereby offers in evidence a certified copy of letters patent No. 404,414, granted to Wm. R. Jones, for method

of mixing molten pig metal, dated June 4, 1889, and the same is marked "Complainant's Exhibit Jones Method Patent."

Counsel for complainant offers also in evidence a certified copy of assignment from Mrs. Harriet Jones, executrix and residuary legatee of the estate of William R. Jones, deceased, to Carnegie Brothers & Company, Limited, said assignment being dated the 24th of October, 1889, and being of various letters patent, including the patent in suit, said assignment having been recorded in the U. S. Patent Office, and hereby marked "Complainant's Exhibit Assignment."

33 *Testimony of James Gayley.*

JAMES GAYLEY, a witness produced on behalf of the complainant, first having been duly sworn, testifies as follows:

It is hereby stipulated between the respective parties that the witness, James Gayley, having been examined as a witness for the complainant in the suit of The Carnegie Steel Company, Limited, *versus* The Maryland Steel Company, *et al.*, in the United States circuit court, for the district of Maryland, for the purpose of expediting this examination, the following part of that deposition shall be taken as the opening part of his present deposition, to wit: Questions 1 to 8, and questions 10 to 11 inclusive, together with all the exhibits offered in evidence therein and all the exceptions on part of the defendant thereto, subject to the right of defendant's counsel to cross-examine thereto; and further it is agreed that defendant's counsel can use any part of the cross-examination of said witness in said deposition as part of his cross-examination in the present deposition.

In accordance with the above stipulation, the examiner embodies said questions and answers upon the record as follows:

Direct examination:

Q. 1. State your name, age, residence and occupation.

A. James Gayley, age 39 years, residence Pittsburg, Pa., occupation, I am connected with the ore department of the Carnegie Steel Company Limited, at the present time. From 1885 until 1892, I was superintendent of the Edgar Thomson blast furnaces, from 1892 until March, 1895, I was general superintendent of the Edgar Thomson steel works.

Q. 2. Please state what experience you have had in and about the operation of blast furnaces and converters, and what has been your study and scientific education with reference to these matters?

34 A. I prepared myself as a metallurgical engineer and chemist by taking a full course at Lafayette college, graduating there in 1876, and from 1876 to 1880 I occupied the position of chemist at the iron works. From 1880 to the present time I have been superintendent of blast furnaces and steel works.

Q. 3. Please state with what iron works you have been connected since 1876, and in what capacity?

A. I was chemist for three years with the Crane Iron Company in the Lehigh valley, Pennsylvania, as chemist. One year as chemist with the Missouri Furnace Company in St. Louis; then I was made superintendent; and in 1882 was connected with the E. & G. Brook Iron Company of Birdsboro, Pa., as superintendent of their blast furnaces; and in 1885 came to the Carnegie Steel Co., then Carnegie Brothers & Company, as superintendent of their blast furnace department, and have been in their employ since.

Q. 4. During your work have you given any attention to the literature on the subject of iron and steel manufacture, and have you done any writing for scientific periodicals or scientific societies?

A. I have been constantly a subscriber to all the magazines and trade journals published in this country and abroad since commencing my career as a chemist. I have been a member of the Iron and Steel Society in this country and in England, and have contributed papers to both societies relating to the manufacture of iron.

Q. 5. I show you volume XIX of the Transactions of the American Institute of Mining Engineers, and ask you who is the author of the article printed on pages 932 to 956, a discussion of which follows from pages 957 to 995. The article is entitled "The Development of American Blast Furnaces with Special Reference to Large Yields. By James Gayley, Braddock, Pa., (from the Proceedings of the New York Meeting of the Iron and Steel Institute, October, 1890)."

(Objected to as incompetent and immaterial.)

A. I am the author.

Complainant's counsel offers in evidence the article mentioned in the last question.

The admission of this article is objected to for the reason that it is incompetent and immaterial, and further for the reason that it is not competent evidence as to any of the matters or things therein contained.

Q. 6. While you were superintendent of the blast furnaces of the Edgar Thomson steel works, did you use there any apparatus for receiving and mixing the metal from the blast furnaces before it was charged into the converter? If you did, will you please describe the same fully, stating its functions and any advantages it may possess, and in order that the matter may be made clear to the court, will you please preface your answer by a general description of the blast furnaces and their work and of the treatment which the metal receives from the time when it is tapped from the blast furnace until it is made into steel and cast into ingots?

(Objected to as immaterial and irrelevant.)

A. The blast furnace for the reduction of iron ore into pig metal

is a cylindrical shaft, varying in height from 60 to 100 feet, and from 12 to 25 feet in diameter at the widest point which is slightly below the middle, tapering therefrom both ways. It is provided with an apparatus at the top for charging the materials, and at the bottom with air inlets for the admission of the blast to burn the fuel, and openings to remove the slag and iron. Into this furnace is charged a mixture of iron ore, fuel and limestone. The fuel is used for removing the oxygen from the ore and melting it subsequently, and the limestone is used for fluxing off the im-
36 purities in the ore as a slag. The materials are charged roughly and in large quantities, and vary very considerably in their chemical composition. The object of the blast furnace in making Bessemer iron is to obtain a metal that runs uniformly in its content of silicon, sulphur, manganese, and carbon, which with the varying character of the material introduced is absolutely impossible even under the very best conditions. It is essential to the proper manufacture of Bessemer steel that the metal should be uniform in the content of its impurities, particularly silicon, as this is the heat-producing element in Bessemer steel making.

In order to obtain a uniform charge of metal for the Bessemer converter when the metal is obtained from several blast furnaces, it is either mixed together in charging it into a cupola and remelted, thus securing an average of the varying grades, or else by pouring it into a metal mixer of large capacity and withdrawing it therefrom for use in the Bessemer converter instead of from the cupola; the metal in the mixer remaining for a long time in a hot state renders this feasible. The metal from the mixer is poured into a Bessemer converter in quantities from, as now ordinarily used, eight to fifteen tons to a charge. Air is blown through this metal at a pressure of from eighteen to twenty-five pounds to the square inch, which burns out the silicon, carbon and manganese, thus rendering it, by the addition of a small amount of spiegel, a certain grade of steel. This steel is then cast into ingots and rolled in the mill into merchantable articles of steel, such as rails, beams, and other structural material.

In the making of Bessemer steel, and in fact in the manufacture of all kinds of steel, the most vital point is the matter of temperature, and the temperature is obtained by the combustion of silicon in the acid process, and by phosphorus in the basic process. We can only obtain temperature in a metal bath through the
37 combustion of an element that remains solid after it is burned. Consequently, in the acid Bessemer process, the silicon in the metal is the heat-producing element, and is what governs the speed of the operation, the quality of the steel and the amount of waste in manufacture; as, for instance, if a heat is blown in a Bessemer converter in which the content of silicon is say half of one per cent., the heat produced is not sufficient to keep the resulting steel sufficiently liquid to cast it properly into molds, and a chill frequently results, causing a total loss of the metal, and in fact if any of it is utilized to the extent of being cast into the form of an ingot, it is in all works condemned as scrap, as being unsuit-

able material for use in any of the products of steel manufacture. If, on the other hand, the silicon is too high, say ordinarily from 2½ to 4 per cent., the time of the conversion from pig iron to steel is unusually long, increased cost results thereby, the amount of oxides is such an uncertain quantity that the proper amount of spiegel, which is a deoxidizer, cannot be accurately determined, and the resulting steel is poor, even if the proper amount of spiegel should be added. This excess of silicon in the metal would require an unusually large amount of spiegel for the proper reaction and would increase the cost thereby, as manganese metal is very expensive.

The aim, therefore, in the Bessemer practice is to obtain a metal that approaches perfection in uniformity of its silicon and sulphur content. This, as stated before, can only be accomplished by mixing the metals together when they are cold and remelting them in a cupola, or by mixing the metals from the furnaces together when they are hot in a metal mixer of large capacity. The cupola requires a large amount of fuel and labor, and is accompanied with a large amount of waste in order to melt the pig iron and obtain a uniform mixture. The metal mixer accomplishes the same results in as satisfactory manner in a far more economical way, requiring a very small amount of labor compared with the other, and
38 with practically no waste and no consumption of fuel; and for this reason, the metal mixer is a much more desirable method of operation. The metal mixer is more desirable in securing this end than the cupolas for remelting, on account of the large waste in the percentage of silicon which occurs in the cupola, requiring an increased amount of silicon in the metal which goes into the cupola, and which increased silicon is produced at a greater expense of fuel and labor at the blast furnaces.

To the best of my recollection, the practice of remelting iron in the cupolas for the Bessemer converters at the Edgar Thomson Steel Works was abandoned in the year 1882. The direct-metal practice was then substituted, which consisted in running the molten iron from the blast furnace into ladles and sending them to the Bessemer department to have their contents poured directly into the Bessemer converter. This metal was taken from one furnace at a time at its proper time of casting. The conditions of blast-furnace work are such that casts of iron are made four or five times a day, and the ladles were brought to each furnace at its proper time of casting, and the metal from that furnace poured into ladles was used as consecutive heats in the Bessemer department.

Under this system of operation, we found that the work in the Bessemer department compared with the former practice by the use of cupolas was very irregular. One cast of iron would be quite low in silicon and would cool off the converters to such an extent that the next cast would have to be taken from a furnace that was higher in silicon than was desired in order to restore the heat in the converter. Sometimes a few casts might be very close in their composition and the results would be very good, but the general experience showed that great variation in compo-

sition was the rule, and so great was this variation that special men were employed at the Bessemer department at high salaries in order to devote their time to the judging and correcting of this variation in temperature induced by the variation in
39 silicon, to overcome the bad results that were obtained, and in addition the force of chemists had to be doubled, and various other expenses gone to in the endeavor to overcome this great variation in composition. As a matter of fact, all efforts in that direction were of no avail, and necessarily must be so when one considers the irregular character in general of blast-furnace operations, as for instance a slight change in the composition of the material charged into the furnace produces an irregularity in silicon in the metal. This variation is again produced by a change in the volume or temperature of the air that is blown in, or by a change in the composition of the slag, and also in a very marked manner by the least change in the content of moisture in the atmosphere, as, for instance, a day in which the atmosphere is very humid, the moisture entering the furnace with the blast requires an undue expenditure of heat in the zone of combustion and produces a metal that is low in silicon. Again, on a day when the atmosphere is very dry, the opposite conditions exist, and there is produced a metal unusually high in silicon, either of which is undesirable in Bessemer steel operations.

As a matter of fact, these casts of low silicon iron which were produced were always rejected and had to be remelted at considerable expense. The conditions surrounding blast-furnace operations are such that it is absolutely impossible to obtain a metal suitable for Bessemer operations when the metal is taken directly from the blast furnaces to the converter without passing through a metal mixer.

The result of these great variations in the composition of the metal and the evident impossibility of regulating the furnaces to produce a metal that was more uniform, induced Capt. Jones to design the metal mixers, which were installed at the Edgar Thomson works, of such capacity that the casts from a number of furnaces of great diversity in the content of silicon could be mixed together, and from which could be drawn out a metal that would be
40 as uniform as that which would be obtained from the mixing and remelting in a cupola. As soon as these mixers were put into operation the beneficial effects were at once apparent. Metal which theretofore varied between the widest limits, as much in fact as two per cent., was now reduced in its variation to a few tenths of one per cent.; and whereas the number of ladles obtained from one furnace did not exceed six at any one time, and averaged about five which were practically of the same composition, the next furnace having the same number of ladles being of quite a different composition and varying in silicon possibly from a quarter of one per cent. to one and a half per cent. from the preceding one, we have instead a whole turn's work consisting of from 55 to 65 of these ladles drawn from the mixer, and which in our average practice would not exceed a variation in silicon of two-tenths of one per

cent. The Bessemer operations at once assumed the uniform character prevailing at the time when cupolas were used. The extra men that had to be employed previously were dispensed with, the quality of the steel was much improved, the waste of steel in chilled heats, which was put out as scrap, was brought back to normal amount.

In the operations of the metal mixer the object is to keep together a large amount of metal in order to ensure a thorough admixture and also to keep the mixers constantly full. In the conduct of our operations at the metal mixer we have rigid orders that the mixers shall never be drained more than one-half, and when the metal through any delay in the supply from the blast furnaces reaches that point the supply to the Bessemer department is immediately stopped. The advantages in the metal mixer are derived principally from keeping together a large quantity of metal, and the best results are obtained when, for instance, two ladles are drawn out and two are poured in to keep them absolutely full, and this condition is maintained throughout the whole week until the mixers
41 are drained on Saturday night. It is not possible to operate these mixers by filling them with metal from two or three furnaces, draining that out, and refilling them again in the same way. We have had experience on this point when through circumstances the supply of metal was limited, and we found that the variation in composition was very marked indeed. Consequently, we have established the hard and fast rule that the mixers must be continually kept full.

I was intimately associated with Captain Jones during the time that this project for a mixer was taking shape in his mind, and the general impression seemed to be that it would be impossible to keep such a large body of metal in a liquid condition for the length of time that would be required to make such mixing a success, and he often mentioned the fact to me that his friends in the iron and steel business had often spoken to him on this point, and expressed their opinion that it would be impracticable and advised against it. The subsequent results showed that his original expectations in regard to the temperature and liquid condition of the metal were carried out. The mixer, as originally designed by him as an experimental one, contained 100 tons of metal, his idea being if it was demonstrated to be a success to construct a larger one. This mixer was rectangular in shape, with a greater depth at the rear or receiving side for the metal, than on the front or pouring side, so that when at rest the metal would have a greater depth and more compactness by resting principally in a deeper portion of the mixer. This rectangular receptacle was constructed with a movable top for the purpose of cleaning, lined throughout with firebrick, and was supported on a shaft, and was moved or tilted by a steam-engine operating through a rack. The metal is poured in through a funnel-shaped opening on the top at the rear side, and poured out through a trough at the front side, which is closed by a door to pre-
42 vent the air passing in to oxidize the metal or silicon. In some cases the mixer has been used, where the character of

iron was such as to be high in silicon, to reduce that silicon to a proper percentage, by leaving all the doors open to admit readily of air which would reduce the silicon very readily. In our practice, however, we did not have this condition existing, and we kept the door closed in order to prevent this action. The first mixer having proved a success, and as the space where we had located it was not sufficient to put in a larger mixer and still utilize the old one, a duplicate mixer was erected, each having a nominal capacity of 100 tons. The practice in operating these two mixers was to pour half of the cast into each mixer, and in drawing the metal, to fill half the ladle from one mixer and half from the other, thereby deriving the same benefit from mixing as would have been obtained by the use of a larger mixer, however with the disadvantage that the metal would radiate more of its heat on account of being in a small bulk.

(Objection is made to such of the foregoing answer as relates to the motives which induced or governed Captain Jones in his action, and to all matters referring to statements of Captain Jones and to his conversations with third parties as incompetent.)

Q. 7. How much metal was it the practice to charge into these mixers, and how much is taken therefrom to constitute the charge of a converter?

A. The practice is to keep the mixers full, the quantity depending upon the amount of scull inside the mixer, I presume on an average the condition of the mixer would average 75 to 80 tons in each mixer during the time between cleanings of same. When the mixers were first built, the converter charge, or amount taken from the mixer for each Bessemer heat, was ten tons. Subsequently this was increased to fourteen tons by an increase in the size of the
43 Bessemer converter, and in order to get the same advantages of the mixer with a larger heat plans have been prepared for an increased size of mixer, but it has not been erected up to the present time.

Q. 8. Then, as I understand you, the metal is taken from the blast furnances in a melted condition, stored in the mixers, and portions of the mixer contents are drawn off from time to time and taken and charged into the converters in liquid condition without remelting?

A. That is the method of operation.

Q. 9. Have you any statements of analyses showing variations in chemical constituents of different tappings from a blast furnace, and the effect of the Jones mixer in making uniform the metal to be used in the converters?

A. I present analyses taken from our records at the works, of date May 28th, 1895, which is an average day's showing, in which the analyses of silicon and sulphur are recorded for each cast in the consecutive order in which these casts of pig iron or molten metal as we term it are poured into the mixer, and likewise the analyses of the alternate ladles taken from the mixer, as follows:

Analyses of consecutive casts from blast furnaces before pouring into metal mixer.

	Percentage of Silicon.	Sulphur.
	2.01	.017
	1.31	.017
	2.05	.023
	1.03	.027
	2.19	.020
	2.17	.018
	1.17	.020
	1.59	.020
	1.10	.021
	2.08	.031
	2.31	.018
	1.66	.016
	.86	.025
	.84	.029
44	1.19	.027
	1.87	.020
	.86	.032
	1.38	.023
	1.47	.025
	.91	.021
	2.10	.021
	.89	.027
	1.66	.027
	1.26	.036
	.75	.038
	1.54	.025
	1.28	.018
	1.77	.025
	.58	.045
	1.26	.038
	1.40	.036

Analyses of each alternate ladle from metal mixer; only alternate ladles are analyzed.

Percentage of Silicon.	Sulphur.
1.35	
1.24	.022
1.75	
1.33	.033
1.35	
1.38	.026
1.37	
1.26	.023
1.37	
1.40	.022
1.35	
1.35	.016
1.40	
1.35	.024
1.40	
1.34	.022
1.26	
1.24	.023
1.14	
1.34	.023
1.21	
1.49	.024
1.40	
1.42	.024
1.24	
1.24	.024
1.17	
1.07	.026
1.14	
1.38	.026
1.21	
1.26	.029
1.14	
1.14	.029
1.21	
1.10	.027
1.17	
1.21	.029
1.24	
1.26	.026
1.19	
1.21	.026

As explanatory of the above table, I would state that the number of ladles from the metal mixer, by reason of taking each alternate heat, is twice as many as here shown, and consequently are a great

many more in number than the analyses shown on the side of the furnace casts, inasmuch as the casts from the furnace contain a number of ladles represented by one analysis. This analysis is made from samples taken from each one of the ladles that go to make up a cast, and consequently represents the average of the cast.

Q. 10. Is Capt. William R. Jones now living?

45 A. He is not.

Said questions and answers of the former deposition of Mr. Gayley having been embodied in the record, the direct examination is further proceeded with as follows:

Q. 11. What effect has the introduction and use of the Jones mixer as described in the patent in suit had upon the direct process of manufacturing steel from cast iron without remelting the metal after it has been tapped from the blast furnace? State also, whether in your opinion, such direct process would be commercially desirable if carried on without the use of the Jones mixer, by which I mean the mixer of the apparatus in the patent in suit, as described therein; and in this connection you may also state such facts as to the history of this matter as may have come to your knowledge.

(Objected to as incompetent, except in so far as the witness may have personal knowledge of the use of the mixing process as practiced under the Jones process in suit. All questions as to the apparatus of the Jones mixer are objected to as irrelevant and immaterial. Evidence as to the history of the manufacture of steel possibly included in this question is objected to, except as to such as the witness can state of his personal knowledge.)

A. The effect of the Jones mixer has been to prepare a metal for the Bessemer converter as uniformly in quality as that obtained by remelting in a number of cupolas. It has furnished a metal for the manufacture of steel that is more pure chemically and thereby produces a better quality of steel, and further, has been the sole means by which molten metal could be used directly from the blast furnace to the converter on a commercial basis, producing steel equal in quality, and uniformly so, to that obtained in prior practice.

The use of the Jones mixer has resulted in the use of a large amount of iron from the blast furnaces that prior to its use had been rejected and remelted; the great variations in the con-

46 tents of silicon in the metal which produced such a variation in the steel and losses in the Bessemer department, are now eliminated; and both the blast furnaces and Bessemer converter can be operated more economically.

In my opinion, the direct process is not and was not commercially desirable before the introduction of the Jones mixer. Numerous attempts had been made prior to its introduction to obtain a uniform quality of metal for the Bessemer department, on the one hand by using at the blast furnaces a few ores of practically uniform composition, and, again, by filling the ladles half full at one

furnace and filling the remainder at another; but from this practice, to my own personal knowledge, no benefits were ever derived.

Prior to the introduction of the Jones mixer, the conditions affecting the use of molten metal were as follows: The metal from the furnace representing from four to six ladles of iron and in weight about ten tons to a ladle, was taken directly from the blast furnaces to the Bessemer department and poured into the converter. Our analyses showed that each ladle in the cast varied from each of the others, and sometimes within very wide limits, and also that the average analysis even from each furnace varied to a great extent from the furnace from which metal was taken just before or after, and that this variation in composition of metal going through the steel works produced great irregularity in practice, by reason of the conditions being so variable; as, for instance, one cast of iron, or a ladle or two in the cast, might be of very low silicon content, producing a chilled heat of steel in the Bessemer department, causing a loss of metal and injury to the apparatus. In order to offset the ill effects that were produced, which consisted partly in cooling down the converters to a great extent, the next cast would have to be drawn from a furnace that was abnormally high in silicon. This was necessary in order to restore the heat in the converter and remove any scull that had been formed, and thus
47 required the operators to work with metal that was widely divergent in composition and likewise in quality.

The objectionable feature in using direct metal from the blast furnace into the converter without an intermediate mixing was, to to sum it up, requiring the men in the steel department to work with metal that was abnormally bad by reason of an excessive quantity of sulphur at one time, and equally so at another with an abnormal quantity of silicon, it being impossible even to approach a mean composition such as obtained from a cupola; nor does the blast-furnace operation, even under the best conditions, permit of such uniformity in product.

The conditions under which a blast furnace is operated are such, that the slightest change in composition of the ore, fuel, or the limestone, will produce a respective change in the composition of the metal, and even so slight a change in conditions as represented by a change in the content of moisture in the atmosphere produces, all things being considered, the widest fluctuations in the composition of the pig metal; and inasmuch as the conditions of the atmosphere are beyond control, so it is impossible to control the product of a blast furnace in point of uniformity of composition, and it is therefore certain that the uniformity of metal produced from a cupola cannot be obtained in a blast furnace, and must therefore require a mixing of metals after the same purpose as shown by a cupola, and for this purpose the metal mixer was designed.

Q. 12. In your last answer, where you say that the use of the Jones mixer has been the "sole means by which molten metal can

be used from the blast furnace to the converter on a commercial basis, giving steel equal in quality, and uniformly so, to that obtained in prior practice." Please state what you refer to by the expression "prior practice" in your answer as quoted?

A. By prior practice I refer exclusively to the cupola practice.

48 Q. 13. State what is the difference between what you refer to as cupola practice and the direct process.

A. The difference consists in that the cupola practice furnished a metal for the Bessemer converter that was uniform in composition, or practically so, while the direct metal was as variable in composition as it was possible for a blast furnace to fluctuate in grade of its metal.

Q. 14. Please to state for the information of the court, what was the cupola process, and in what way that process enabled the parties using it to obtain a definite quality of iron as the product of the cupola, and how in this respect the direct process differed; that is to say, I want to know the cause of the difference which you have referred to in your last answer?

A. The cupola process consists in melting pig iron in a cupola furnace with coke or coal as a fuel. The pig iron with which a cupola is supplied is piled in the yard according to its composition, and in order to obtain a definite quality of iron as the product of the cupola, it became necessary to make an admixture in the charging barrels that supplied the cupola of the iron from the piles in the yard, each of a definite composition, which on being melted with a small and uniform percentage of loss, gave a definite quality of metal in the product.

The direct process, on the other hand, took molten metal from blast furnaces, in which each ladle differed from the next in composition, and each furnace cast differed in composition from the next furnace cast, thus preventing the furnishing of a molten metal of a definite quality.

The cupola furnished metal of a definite and uniform quality continuously. The direct-metal process furnished molten iron varying in composition to wide points.

Q. 15. Then am I right in understanding you that the character of the charge in the cupola was known and could be regulated as desired to yield a definite product, while in the direct process,

49 the iron being obtained by the reduction of ore in the blast furnace, the character of the resulting metal is irregular and uncertain?

A. That is the state of the art.

Q. 16. Will you please state whether you have ever seen the plant of the defendant at the Cambria iron works for mixing metal for the converters?

A. I have.

Q. 17. Can you state when it was that you saw it?

A. To the best of my recollection, it was in November or December, 1895.

Q. 18. Have you any means by which you could fix the date more definitely?

A. I may possibly find an entry in my diary; if so, I will furnish it.

Q. 19. Can you describe the apparatus which you then saw at the Cambria iron works? Before answering this question, I show you a couple of blue prints of the apparatus of the defendant, which blue prints have been furnished to complainant's counsel by defendant's counsel, at the request of the former, in order to facilitate and hasten the *prima facie* proofs in this case. You may look at these blue prints, and state if they correctly represent the apparatus referred to in my question.

A. The drawing of the mixer which I mark with a letter *A* is the design of the metal mixer that I saw at the Cambria iron works at the time of my visit. It consisted principally of a vessel the shape of a turtle shell, arranged to tilt and having a spout at either side for receiving and pouring out the metal. The metal was brought to the mixer and poured in on one side, and through a spout on the other side was poured into a ladle, which supplied the Bessemer converters.

Q. 20. This vessel which you have called a mixer was designed to be supplied with metal direct from the blast furnaces, by what means?

50 A. It was designed to be supplied by ladles on trucks which received the molten metal at the blast furnaces, and were transported to this vessel and poured in.

Q. 21. State whether or not the mixer which received the molten iron from the blast furnaces was provided with any cover.

(Objected to as immaterial.)

A. It was provided with a roof which was a part of the mixer.

Q. 22. What provision, if any, is made in the apparatus for the discharge of the metal from the mixer into the ladle, which you have referred to as supplying the converters with molten iron?

A. The mixer was provided with a rack which was operated by a pinion and driven from an engine which caused the mixer to tilt or roll in its position in order to discharge the metal.

Q. 23. How was the tilting of the mixer rendered feasible, and on what was the mixer supported?

A. The mixer was supported on rollers which were supported in a frame, and in tilting the mixer moved on these rollers.

Q. 24. What was the shape of the under side of the mixer?

A. Semicircular.

Q. 25. In the drawing which you have referred to, what is the part which I have marked *B*?

A. *B* represents the ladle transporting the metal from the blast furnaces to the mixer; in the upper position shown in dotted lines, it is represented as discharging the metal into the mixer.

Q. 26. What is the part which I have marked *C*?

A. *C* is the ladle that receives the metal from the mixer, and conveys it to the Bessemer converter.

Q. 27. What is the part which I have marked *D*?

51 A. *D* is the Bessemer converter. I would make a correction in regard to the manner in which the mixer is operated, my recollection of this being confounded with another. In this case, at either end of the mixer, are two cylinders with rods which are fastened on by a pin at the end of the mixer, and by hydraulic power the mixer is made to revolve on the rollers mentioned above to whatever point is necessary to discharge the metal.

Q. 28. In the apparatus you have referred to and as you saw it at the works of the Cambria Iron Company, state whether or not the mixer was arranged so as to be supplied with metal from blast furnaces?

A. It was.

Q. 29. As near as you can recollect, with how many blast furnaces was this mixer arranged?

A. I presume it was arranged with all of their blast furnaces, although I did not visit the blast-furnace department.

Q. 30. So far as you know, was there more than one mixer such as you have described, at the works of the Cambria Iron Co.?

A. I saw only one mixer.

Complainant offers in evidence blue print furnished by defendant's counsel, and marked blue print No. 1 of defendant's mixer; and so much of blue print No. 2 defendant's mixer as is represented at the left-hand half of the sheet, as to which the witness was examined.

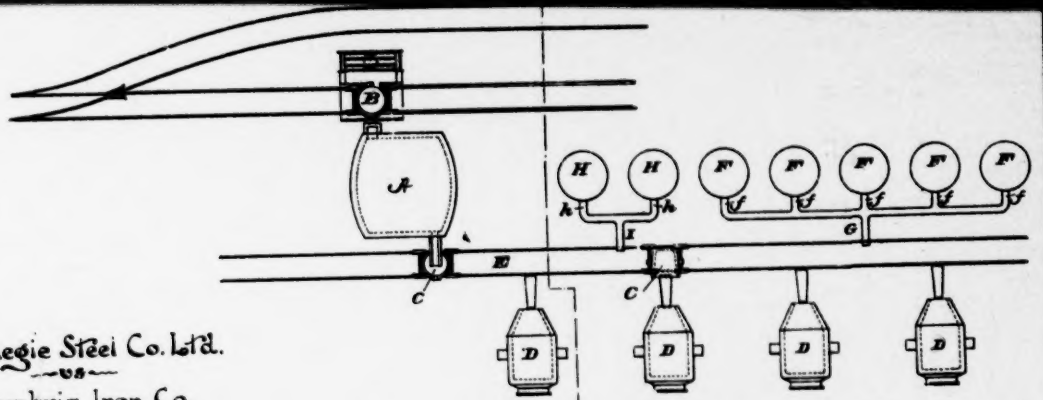
Defendant's counsel, in view of the fact that he freely furnished blue prints of the apparatus complained of and showing the plant as operated by the defendants, inquires of the complainant's counsel if he thinks it is fair only to offer in evidence a part of the last blue print referred to, especially when the plan view of the so-called mixer included in the offer by complainant's counsel, is a part only of a single figure showing the plant.

52 Counsel for complainant replies that the blue prints were used at the offer of defendant's counsel, and for the purpose of expediting the taking of testimony-in-chief, for the convenience of defendant's counsel. That the reason why only a portion of blue print No. 2 is offered in evidence is that, so far as complainant's counsel can see, the part on the right-hand side of the sheet has nothing whatever to do with the case, and was not prepared by complainant or its counsel, and could not in any way serve the purpose for which the blue prints were used for illustrating the testimony of the witness, and that, of course, such use by the complainant's counsel is, in his judgment, perfectly fair inasmuch as defendant's counsel is at liberty to make such use of the remainder of the sheet as he chooses, provided the same will be competent.

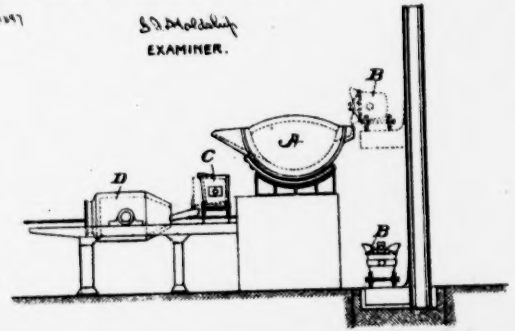
Defendant's counsel while not objecting to the exhibits, especially in view of the fact that he furnished them, does object to the incomplete examination in regard to them, and to the omission of part from the second blue print.

Q. 32. Mr. Gayley, state please whether you saw the apparatus

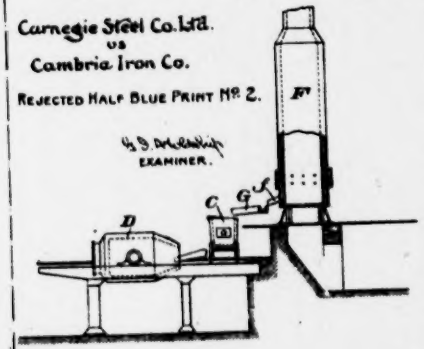
Carnegie Steel Co. vs. Cambria Iron Co. Ep. 52 a



Carnegie Steel Co. Ltd.
—vs—
Cambria Iron Co.
BLUE PRINT No. 2, DEFENDANTS' MIXER.
May 1st 1897
S. D. McCullough
EXAMINER.



Carnegie Steel Co. Ltd.
vs
Cambria Iron Co.
REJECTED HALF BLUE PRINT No. 2.
S. D. McCullough
EXAMINER.



which you have described in actual operation at the works of the defendant at Johnstown, or whether the operation of the apparatus was described to you by any of the officers of the defendant corporation?

A. It was not in operation at the time of my visit, but it was described to me by the officers of the defendant corporation.

Q. 33. The operation described to you by the officers of the defendant corporation was such as you have stated in your testimony, was it not?

A. It was.

Q. 34. Will you please state what was the operation of the apparatus which you have referred to in your testimony as explained to you by the officers of the defendant corporation?

(Here follows diagram marked p. 52*a*.)

53 A. The operation explained to me was in showing how the mixer was operated, how the ladles filled from the mixer were taken to the converters, how the metal from the blast furnaces was brought in the ladle, on the ground at the time, how they were elevated to a point necessary to discharge into the mixer.

Direct examination closed.

Mr. Kay, defendant's counsel, in view of the fact that the evidence of this witness evidently fails to show what the defendant company actually does in the operation of the apparatus complained of, for the purpose of expediting the case, admits upon the record that the defendant company has used a receptacle for molten metal from blast furnaces such as shown in detail in blue print No. 1 of defendant's mixer, and such as shown in blue print No. 2 of defendant's mixer; the plant also being employed in connection with cupolas as shown to the right of said blue print No. 2, and that in the operation of said plant molten metal from two or more blast furnaces was brought from time to time in ladles and introduced into the vessel *A*, and sufficient of this metal to form a charge to the converter was poured from this vessel *A* into a ladle, and then introduced into one of the converters; such charges being taken from time to time as necessary from the vessel *A;* and at other times, in the regular running of the plant, the metal being tapped from the cupola into this ladle and introduced into one or the other of the converters, the metal taken from the receptacle *A* being sometimes mixed with the metal taken from the cupola.

All that part of the foregoing admission which refers to the use of cupola furnaces is objected to as immaterial, incompetent and irrelevant.

Mr. Kay, for the purpose of limiting the volume of the record as far as possible, inquires of Mr. Bakewell whether it is the intention of complainant to insist upon infringement of the two claims of the patent in suit, and if not, on which of said claims he proposes to stand at the hearing.

54 The question of defendant's counsel will be answered at the proper time before defendant takes its rebutting testimony if the question should be repeated.

The question put by Mr. Kay was put at this time in order, if possible, to shorten the necessary cross-examination of the expert witness on the stand, and he thought it proper for that reason.

Complainant's counsel replies that inasmuch as defendant has offered to the complainant drawings purporting to be a correct representation of defendant's plant, showing in connection with the mixer cupola furnaces which have nothing to do with the direct process, and failing to show any connection with blast furnaces, which it is now admitted that defendant uses, complainant feels warranted in withholding an answer to the question of defendant's counsel, until complainant's testimony-in-chief shall have been closed.

Cross-examination by Mr. KAY:

In accordance with the stipulation at the opening of this witness' examination, defendant's counsel adopts as part of his cross-examination the entire cross-examination of this witness in the said suit of The Carnegie Steel Company, Limited, *versus* The Maryland Steel Co. *et al.* The examiner therefore embodies such cross-questions and answers on the record as follows:

X Q. 35. Have you read, and are you familiar with the patent to William R. Jones, No. 404,414, on which the present suit is based?

A. I have never read it.

X Q. 36. You have said in substance that you are familiar with the literature relating to the manufacture of steel. To what extent, if at all, are you familiar with the state of the art as described in the various British letters patent?

55 A. I am only familiar with the manufacture of iron and steel from what I have personally seen of it in this country and in Europe and what has been described in trade publications and the reports of scientific societies.

X Q. 37. In testifying with reference to the Jones mixing process, was it your understanding that he was the first person to mix the molten product from different blast furnaces in order to secure an average or more uniform product for use in the converter?

A. Capt. Jones is, as far as my knowledge goes, the first person to have attempted the mixing of molten metal from different furnaces for use in a Bessemer converter.

X Q. 38. That mixing of molten metal from different furnaces for use in a Bessemer or other converter is the very pith and essence of the Jones process, is it not?

A. I understand it so.

X Q. 39. Am I correct in understanding you to say that so far as securing uniformity of the charge for the converter is concerned, it makes no difference whether the entire charge is taken from the mixer, or whether it is taken partly from the mixer and partly from the cupola?

A. It does not, except that there is a benefit in mixing the molten

metal for use in a Bessemer converter in a metal mixer, arising from the fact that in melting pig iron in a cupola a large amount of sulphur is absorbed from the fuel to such an extent sometimes that it is injurious for the making of steel, while in the mixer there is a slight diminution in sulphur, although in amount scarcely appreciable in practice.

X Q. 40. When the converter charge is taken partly from the mixer and partly from the cupola, you have, however, a mixture or combination containing a greater number of casts or elements than when it is taken from the mixer alone, do you not?

A. The mixture would be improved by the addition of the metal from the cupola which would be equivalent to the admix-
56 ture of another furnace cast in the mixer, and the mixed metal from the two would be improved in point of silicon, but would be injured in point of sulphur content through the introduction of an increased quantity of this element from the cupola. I am assuming in this case that both cupola and mixer are operated under the best possible conditions. Answering the question generally, the more units mixed together, the better the mixture.

X Q. 41. In practice, does the number of casts or units which are mixed together for delivery to the converter, remain constant, or is there a variation in the number of such units from time to time during the course of operations at the Edgar Thomson works?

A. Our practice is to keep the mixers full of metal continually, and as soon as the metal is withdrawn to immediately supply the mixer with the same amount as withdrawn. We use seven blast furnaces for this purpose, and iron from these successive casts are poured into the mixer, and as far as our operations extend, the aim is to carry on this practice continuously, so as to have the same number of casts in the mixer, and while this is true from day to day, and for weeks and even months at a time, yet there are occasions when a furnace may be off for repairs, or may be changed to special metal, thus reducing the number of furnaces furnishing the supply which cast uniformly and are poured regularly into the mixer.

X Q. 42. So far as the principle or method of equalizing the quality of the metal is concerned, is it necessary that you should mix together any particular number of casts or units, or is the difference merely a difference in degree with the advantage in favor of the greatest number of units in the mixture?

A. It naturally follows that the larger the number of casts that can be mixed together the better, and the more uniform is the
57 metal withdrawn therefrom. Yet I have observed in practice that even the admixture of two casts together produced very satisfactory results.

X Q. 43. Assuming that you have two or more smelting furnaces and that you have from each of these furnaces a channel or lead to a vessel which is placed low enough for the molten metal to flow from the blast furnace to this receiver, which forms a receptacle for

mixing the molten metal from two or more of the smelting furnaces, and that from this receiving vessel the metal is tapped and flows into the converter, would that give you a mixing process for equalizing the quality of the metal going to the converter?

(Objected to as improper cross-examination, and is further objected to unless the witness is shown a full drawing and description from which counsel now makes an extract, so that the construction and mode of operation of the apparatus mentioned may be made clear, and so that it may appear whether a whole or what part of the contents of the so-called receiver are tapped therefrom before further additions are made thereto. It is submitted that it is unfair thus to put at the witness incomplete hypothetical constructions which would require him to speculate in the dark concerning the same.)

A. If successive casts from two or more furnaces were run into a common receptacle directly from the furnaces, with sufficient time for creating the admixture of the quantity so run in, I would consider that the mixing was as good as a metal mixer, providing that the metal in this receiver would be subjected to the same oscillation as is given to the metal in the operation of a metal mixer in discharging its heats, but as a continuous operation, I cannot venture an opinion as to its ability to produce a uniform mixture of metal without knowing the conditions under which it is operated.

X Q. 44. The Jones mixer so called is simply a vessel into which different casts or charges of molten metal differing in character are delivered in order that they may be commingled and an average or uniform metal produced?

58

A. I consider the Jones mixer an apparatus in which by such commingling a uniform metal can be produced continuously.

X Q. 45. If the quantity of metal in the Jones mixer is permitted to fluctuate to the extent of say twenty-five or thirty per cent., what would be the result as regards the process of mixing?

A. Naturally, the mixing would not be as thoroughly performed.

X Q. 46. The difference, then, if I understand you, would be a difference in degree, and not a difference in kind?

A. It would.

X Q. 47. So far as increasing the uniformity of the product is concerned, am I to understand that the principle of mixing is the same whether two or four or ten or twenty units or casts are commingled?

A. I understand it so.

X Q. 48. But the greater the number of units which are mingled, the more perfect the result?

A. Certainly.

X Q. 49. How much metal passes through one of the mixers at the Edgar Thomson works per day?

A. We pass through one mixer an average, when we are operating at our ordinary speed, of 800 tons of metal every 24 hours.

X Q. 50. You have no way of identifying the elements, or know-

ing that any portion of the metal contained in the mixer at one time remains therein at any other time?

A. Yes, sir, we can. An illustration in point, and which I had in mind in my former statement, was wherein we had charged unwittingly into the mixer in the morning some iron that contained a considerable quantity of manganese which produced an injurious result at the steel works, and under the ordinary process of
59 operation it was in the afternoon before the analyses of metal from the mixer were reduced to the normal percentage.

X Q. 51. But where you use the normal ordinary metal such as you used in the regular practice, you are not able to identify any portion of it, and say that it remained in the mixer, are you?

A. We are not.

X Q. 52. During what time were you associated with the patentee Capt. Jones?

A. From September, 1885, until September, 1889, when he died.

X Q. 53. Are you aware that Capt. Jones, previous to the installation of the mixer at the Edgar Thomson works, visited Europe, and there inspected various steel works?

A. I know that Capt. Jones visited Europe, but his first visit after my connection with him in 1885 was two weeks after the mixer was installed.

X Q. 54. Will you state as nearly as you can when the mixer was installed at the Edgar Thomson works?

A. So far as my recollection serves me, it was in July or August of 1887.

X Q. 55. Referring to the analyses which you have produced, were they made by you?

A. They were not.

X Q. 55½. At what date was it that Capt. Jones was developing his idea of a mixer as referred to in your testimony?

A. To the best of my recollection for about a year before it was put in operation.

X Q. 56. The direct metal process of making steel by taking the metal from the blast furnaces to the converter with remelting was known in the art for many years prior to 1888, was it not?

A. It was.

X Q. 57. And for many years prior to 1888, this direct
60 process of making steel was generally known to those skilled in the art, and practiced to a greater or less extent, was it not?

A. It was.

X Q. 58. For a number of years prior to the construction of the Jones mixer, it was common, was it not, to use in the United States vessels of different sizes lined with refractory material, and adapted to hold molten metal? I mean for different purposes.

A. What is known as ladles lined with refractory material were in use at steel works, capable of holding about 30,000 pounds of steel.

X Q. 59. The mixing vessel used by defendant differs in form

and in the devices for operating it widely from that used at the Edgar Thomson works, does it not?

A. The shape and the manner of tilting it are different from that used at the Edgar Thomson works.

X Q. 60. In defendant's works, the turtle-shaped vessel is tilted or rolled over on supporting pinions or rollers to discharge the metal into the ladle?

A. Yes.

X Q. 62. When did you commence the practice at the Edgar Thomson works of keeping the mixer filled?

A. From the time we started the mixer.

X Q. 63. Since you were examined as a witness in the Maryland case, the substantial part of your deposition in that case forming part of this examination, have you read the patent to William R. Jones, No. 404,414, on which this suit is based?

A. I have not.

X Q. 64. Will you please read that patent between our adjournment today and the resumption of taking of testimony tomorrow morning, so that you may be informed as to what the actual invention, suppose- to be covered therein, is?

A. I will.

61 X Q. 65. When you were at the defendant's works, you were, I believe, in their converter-house, and not in the blast-furnace department?

A. That is true.

X Q. 66. Is it within your knowledge that the blast-furnace department is situate some distance from the converter-house?

A. Part of their blast-furnace plant is situated quite close, and another part is situated further off.

X Q. 67. When you were in their converter-house you saw the different converters, such as shown on the right side of the blue print No. 2, did you not?

A. I did.

X Q. 68. Did you also see within the converter-house the track extending from the vessel A along the front of these converters, which track I mark E?

A. I did.

X Q. 69. And did you see the cupola furnaces arranged as shown in this blue print?

(Question objected to as incompetent and irrelevant, and for the further reason that it is not proper cross-examination. Attention is also called to the fact that part of the drawing marked by counsel for complainant and referred to in the question, has not been offered in evidence; and to save further objections as to this point, it is stated that all testimony referring to the cupola furnace shown in the blue print must be considered as testimony on part of the respondent, and as to which he makes this witness his own, counsel for complainant being in nowise responsible for the drawing of the cupola furnaces.

Mr. Kay calls the attention of the court to the witness' answer 11,

as well as to questions and answers 12, 13, 14 and 15, in which he was fully examined in regard to cupola practice, showing that this line of examination is perfectly proper, and he refuses to
62 consider the witness as his own, and continues his cross-examination, which would seem to be thus perfectly proper in view of the direct examination.)

A. I did.

X Q. 70. Those furnaces were arranged in two groups, one group having five cupola furnaces with the runners therefrom united and leading to a single filling spout, said five furnaces being each marked *F*, and their runners *f* leading to the spout *G*, and the other group having two furnaces, which I mark *H*, their runners *h* being united to the spout *I*. Is this correct?

(Objection continued, it not being waived in view of the statement on part of counsel for defendant.)

A. I do not remember anything about the arrangement in detail.

X Q. 71. Do you remember that the charging ladle which I mark *C* travels along the track *E* in front of the line of cupolas?

(Objection continued.)

A. I do.

Adjourned to meet tomorrow, May 22, 1896, at 10 o'clock a. m.

PITTSBURGH, *May* 22, 1896.

Met pursuant to adjournment.
Present, as before.

Cross-examination of Mr. GAYLEY resumed:

X Q. 72. Did the officer or officers of the Cambria Iron Co. inform you at the time of your visit that in the operation of their Bessemer plant which you then inspected, they sometimes tapped the metal from the cupolas and introduced it into the converters?

A. I do not recall their having made such a specific statement on my visit.

63 X Q. 73. You know, however, that it was, or had been the custom in these works to do that, did you not?

A. I saw that done on my former visit.

Defendant's counsel now offers in evidence the remainder of the blue print, one-half of which was offered in evidence by complainant's counsel, and marked "blue print No. 2, defendant's mixer." The portion of said blue print now offered in evidence is marked "rejected half blue print No. 2."

Objected to by complainant's counsel, for the reason that the half of the blue print was not rejected by complainant's counsel, but was not offered in evidence, as irrelevant because, as complainant's counsel understands, it was designed to show an arrangement of cupolas, and not any apparatus connected with the direct process.

Defendant's counsel has simply offered the remainder of the drawing in evidence to show the plant which the witness actually saw, and which he has, on cross-examination, acknowledged that he saw.

Counsel for complainant suggests that the witness probably saw a large amount of apparatus which has nothing to do with the present controversy and is equally irrelevant, and might just as well have been included in the drawing.

Defendant's counsel suggests that the relevancy of this matter will be made very clear before the examination is concluded.

X Q. 74. You said yesterday in your testimony that by the use of the Jones mixer you furnished a metal for the manufacture of steel that is more chemically pure. What did you mean by this?

A. I mean by furnishing a metal that is more pure chemically, that it contains in the average working of the mixer process a metal with one-half the percentage of sulphur that is obtained by the cupola process.

64 X Q. 75. You mean then, that because the metal is not reheated in the cupola, it has not the opportunity to absorb the sulphur from the coke or other fuel, and for this reason the percentage of sulphur is less. Is that correct?

A. That is correct.

X Q. 76. Prior to the use of the Jones mixer, the complainant company, or its predecessors, (and we will in future include both in the term "complainant company") used the metal direct from the blast furnace, introducing it in its molten state into the converters, did they not?

A. They did.

X Q. 77. About when did they commence to use it?

A. To the best of my recollection about 1882, although I was not connected with the company until 1885, but was advised it had been in use about three years before.

X Q. 78. And I believe the Jones mixer was first installed in the summer of 1887; is that correct?

(Objected to as entirely immaterial and irrelevant, and as improper cross-examination.)

A. Yes. As far as my recollection goes, it was in July or August, 1887.

X Q. 79. Were the complainants doing a regular business in the manufacture of Bessemer steel during the years 1882 to 1887?

A. They were.

X Q. 80. They were at that time doing a large business, were they not?

A. I think they were, throughout a part of the time.

X Q. 81. Can you state, either from an examination of the records or from your own knowledge, the tonnage of Bessemer steel produced by the company, say yearly, from 1882 to 1887?

A. I cannot tell from my own knowledge what the tonnage was.

X Q. 82. Can you examine any records to furnish this information to the court?

65 (Complainant's counsel requests the defendant's counsel to state for what purpose the information is wanted.

Defendant's counsel, in answer, states that the relevancy of the question will be apparent as showing the extent of the manufacture of Bessemer steel by the employment of metal direct from the blast furnaces, prior to the employment of the invention in controversy. He has no desire to pry into the affairs of the complainant company further than for the purposes of this case, and states that approximate figures will be satisfactory.

Objected to as immaterial, irrelevant and not proper cross-examination.)

A. I can only obtain those records with the consent of the president of the company.

It is requested by defendant's counsel that the witness do so.

X Q. 83. During these years, from 1882 to 1887, it is a fact, is it not, that the output of Bessemer steel by the complainant company was greater than any other single Bessemer works in this country?

(Objection continued.)

A. I cannot so state of my own knowledge.

X Q. 84. Well, you do know, at least from the years 1885 to 1887, that the works were producing a very large product of Bessemer steel?

A. They were producing a large output, but not very large in comparison with their practice of today, or what is considered very large today.

X Q. 85. Your practical knowledge of the use of a mixer or receiving vessel into which metal from blast furnaces is introduced was obtained at the Edgar Thomson works, I believe?

66 A. Principally at the Edgar Thomson works, and also by frequent visits to the Maryland Steel Company's mixer, and the Illinois Steel Company's mixer.

X Q. 86. About what is the capacity of the mixer at the Edgar Thomson works?

A. There are two mixers at the Edgar Thomson works, each with a nominal capacity of 100 tons.

X Q. 87. What do you mean by "nominal capacity"?

A. I mean by "nominal capacity," that when the mixer is newly lined, it will hold 100 tons, but that in the process of operation it accumulates some scull, which reduces the actual capacity to 80 or 90 tons.

X Q. 88. These mixers, I presume, are of the same construction as shown in the drawings of the patent in suit?

A. They are.

X Q. 89. Is there any means employed for heating the mixer?

A. Yes.

X Q. 90. What?

A. The mixers are provided with a burner for natural gas, and in the event of having no supply of natural gas, they are heated with

wood, but could be heated with oil in a burner similar to that which we use for natural gas.

X Q. 91. Are they so heated continuously?

A. They are not.

X Q. 92. Then they are only heated when you are preparing them to receive the metal?

A. That is correct under our present system of operation, although when first introduced we occasionally heated them when deemed necessary during the operation.

X Q. 93. Then as I understand heating during the regular use of the mixer is considered optional?

A. I would so consider it.

X Q. 94. Please look at the drawing of the Jones patent in suit, and state where the gas burner is introduced for the purpose of heating the vessel?

67 A. The gas burner is introduced in the discharging spout 6. The products of combustion escape through the inlet iron spout 5.

X Q. 95. And when you heated with wood you think they built a fire within the body of the vessel. Is this correct?

A. That is the method we use with wood.

X Q. 96. How long has it been the custom to your knowledge to heat converters, ladles, or other vessels to receive molten metal before introducing the metal into the same, either with wood building a fire within the body of the vessel, or by means of gas or oil introduced by means of a pipe?

(This question and this line of examination is objected to as irrelevant, immaterial, and not proper cross-examination.)

A. Of my own personal knowledge, since the time that I saw the first ladle in 1870.

X Q. 97. Referring to your practice at the Edgar Thomson works, about what is the largest tap of metal that you take from any one blast furnace at one time?

A. We have taken on a Sunday night in filling the mixers, in order to gain time, as much as 100 tons.

X Q. 98. How many furnaces have you that you get that product from?

A. We have none that we can get that product from, except occasionally. There are three furnaces that would give us this occasionally.

X Q. 99. Well, in getting such tap from the furnace, would you introduce it all into the mixer?

A. We would introduce it all into the mixture, but not continuously, or at one time.

X Q. 100. Well, how would you introduce it?

68 A. When we have such a large tap of iron we, for instance, pour half into the mixer, hold the remainder in ladles until another furnace has been tapped and poured in, and then follow with the remainder. Our object in so doing is to obtain the

benefits of a thorough mixing by the operation of pouring into the mixer.

X Q. 101. You obtain the mixing operation then by the pouring of the metal into the mixer, do you?

A. The principal part of the mixing of the metal is obtained by pouring the new charge into the old, but is further increased by the tilting of the vessel for discharging, and by the general law of diffusion of metals, which always prevails in liquids of varying compositions.

X Q. 102. In your testimony yesterday you referred to the fact that in the old practice "the metal from one furnace, representing from 4 to 6 ladles of iron and in weight about 10 tons to a ladle, was taken directly from the blast furnace to the Bessemer department and poured into the converter." Am I right in understanding that you meant that these separate ladles formed one cast from the blast furnace?

A. Yes. They would represent one cast, and were poured into the converter to make successive heats of ten tons each.

X Q. 103. You also say that the analyses showed that each ladle in the cast varied from each of the others, and sometimes within very wide limits. Would the advantage of obtaining homogeneity of metal, such as you have described in the use of the Jones mixer, have been obtained if the metal in the several ladles had been first introduced into the mixer and then tapped therefrom to the converters?

A. Do you mean if these several ladles were alone introduced into the mixer?

X Q. 104. You can take it that way in answering.

A. You would not, for this reason,—that the mere mixing together of a small quantity of iron of heterogeneous composition,
will not produce a uniform metal like the continuous
69 operation of a metal mixer; as, for instance, the admixture
of so many ladles as mentioned might, by rapid mixing, as would necessarily be the case, produce a mixture, the composition of which might still be an unsatisfactory one for the manufacture of steel. Whereas, with the metal mixer, the first requisite of which is that a large body of metal shall be commingling at one time, and that the process of making uniform, ununiform material, requires a considerable period of time, and that this element of quantity and time during commingling is an essential cause of the uniform results that are produced by the metal mixer; while the commingling of small quantities without the time for commingling, which must necessarily follow in the operation of a plant, will not give the same uniform results, or anything approaching that obtained by the metal mixer.

X Q. 105. Will you please state whether, under the conditions of questions 103 and 104, in introducing the metal from these several ladles, you would not equalize their chemical composition by commingling and mixing together the liquid metal?

A. I would say that the question of equalizing would be simply one of degree, and of such degree that the commingling of this

quantity of metal, and under such conditions, would not be commercially profitable, whereas a commingling of the same quantity of metal with that ordinarily carried in a metal mixer, would render it commercially profitable; and my reason for so stating is because in the operation of a steel plant the commingling operation would be very short, and the time necessary for a thorough diffusion would not take place.

X Q. 106. I would like a direct answer to my question, which I will reframe. Supposing that you introduced into a mixing vessel or receptacle the metal from one cast of a blast furnace contained in 4 to 6 ladies, the analyses of the metals showing that the metal in each ladle differed from the others, would you in so doing
70 equalize their chemical composition by commingling and mixing together the liquid metal? Please answer yes or no.

(Objected to as irrelevant and not proper cross-examination, and the witness is instructed that he is not compelled to answer yes or no, if such an answer would not conform to his opinion in the matter.)

A. There is not enough data given in the question to answer yes or no.

X Q. 107. I do not see wherein the question is faulty, but if it will aid you in answering it, you can consider that the metal from each ladle is poured successively into the mixer or vessel?

(Objection continued.)

A. That does not give me the information necessary.

X Q. 108. What information more do you want?

A. I want to know the time that is allowed for the commingling.

X Q. 109. You can consider that there is sufficient time for the commingling of the metal?

(Objection continued.)

A. With sufficient time being given to make it, as a theoretical question, I would answer, yes.

X Q. 110. Referring to the mixing of the metal, you say that it is increased by the tilting of the vessel for discharging. Do you mean to say that the mixture is improved by the pouring out of the stream from the mixer?

A. I mean to say that the disturbance of the metal undoubtedly increases the commingling of the ingredient charges in the mixer according to the degrees of disturbance.

X Q. 111. Then this disturbance occurs within the vessel and by the movement of the vessel, and that is what you mean by tilting. Is that correct?

(Objected to because the witness did not say that the disturbance is tilting.)

71 A. I mean that the movement of the vessel produces a disturbance in the metal contained therein.

X Q. 112. And this disturbance is caused by the tilting of the vessel?

A. I would say that this disturbance is caused by the tilting, or any other movement, that is given to a mixer.

X Q. 113. The mixer, in connection with which you have had your practical experience, is the one shown in the drawings of the patent in suit, especially in figure 1, where it is deep at one end, shallow at the other, and has an inclined bottom?

A. Yes, that is the shape.

X Q. 114. About how often is this mixer tilted?

A. On an average of five times per hour.

X Q. 115. Does not the tilting of the mixer in use in your works, and such as shown in the patent drawings, impart a movement to the metal longitudinally of the vessel, which causes an agitation throughout the mass?

A. It does.

X Q. 116. When you used the blast-furnace metal direct without the employment of a mixer, you made careful selection of your ores introduced into the blast furnace?

A. What do you mean by a careful selection? We made mixtures of the ores as furnished us in such proportions as to make a Bessemer iron.

X Q. 117. In your direct examination you say that you used a few ores of practically uniform composition. Do you mean by this that you selected your ores in order to produce as uniform a metal as practicable?

A. We have always done that.

X Q. 118. Do you mean that you made no change in this practice after you used the mixers?

A. No, we have made no change. As a matter of fact, to explain, we have always made a mixture out of the ores that have been purchased in order to enable the furnace to run as long as possible on a uniform ore mixture.

72 X Q. 119. Suppose you have a heated vessel, such as a furnace chamber or hearth, into which you pour a heat or tap from a blast furnace, and to which is afterwards added another heat or heats, taken from the same or another blast furnace, would the metal under these circumstances mix and average in composition?

A. As a theoretical question, I should say it would if given the proper element of time.

X Q. 120. In following this practice, would you be employing the Jones process as you understand it?

(Question objected to because it is improper cross-examination, as the witness was not interrogated in chief as to the scope of the patent in suit, or as to his opinion thereof, the fact being that in the beginning of the examination of this witness it was stated that he had never read the patent in suit.)

A. As I am familiar and have practiced the Jones process of mixing metal, this would not be following the Jones process,

which process consists, as practiced by us, in adding, from time to time, a small quantity of metal to a much larger one, whereas this, as I take the question, is adding an equal or a larger quantity of metal to a smaller; and, further, the Jones process consists in a continuous operation, which is not indicated in the question as given.

X Q. 121. Consider again my question 119, understanding, if you will, either that you are pouring a small quantity of metal into a larger quantity, or *vice versa*. Will you please state whether, in so doing, you would equalize the chemical composition of the two metals by commingling or mixing together the liquid metal charges?

A. You would, if the proper length of time was given for the commingling operation.

X Q. 122. Considering the Jones process in its broadest view to cover the equalizing of the chemical composition of the crude
73 metal by commingling or mixing together the liquid metal charge, and subsequently refining the mixed and equalized charge, would you be practicing this process if, after treating the metal as stated in Q. 119, you subsequently refined the metal in the converter?

(Question objected to because the present witness was not put upon the stand in regard to the scope or limitations of the patent in suit. This objection, of course, is not intended to apply to any statement of the witness as to his personal opinion concerning the operation and results described in said patent.)

(Defendant's counsel states that the question in itself describes the supposed Jones process without referring in any way to the patent, and understanding the witness to occupy the position of a practical expert, skilled in the manufacture of Bessemer steel, he believes it to be proper examination.)

A. The treatment of the metal after the manner indicated in X Q. 119, I would, with the explanations that have been brought out as to what that process means, consider to be practicing this process, assuming it to be a continuous one.

X Q. 123. Considering the Jones process to be as stated in my last question, would you think it would be practiced if you poured a heat or tap from a blast furnace into a vessel, whether it be a furnace chamber or not, and subsequently poured other heats from the same or other blast furnaces into this vessel so that the metal would mix and average in composition and subsequently refining the metal in the converter?

(Question objected to, for the reason that the process invented by the defendant's counsel as a modification of the Jones process, or what he supposes to be the Jones process, is not one which counsel for defendant has any right to submit to the witness, unless he chooses to make the witness his own, and it is submitted that
74 it is improper to put to this witness hypothetical questions as to the supposed apparatus and its operations which would require him to speculate in the dark concerning the same.)

(Defendant's counsel states that this witness has under direct examination at very considerable length set forth what he understands the Jones process to be and its advantages, and it is eminently proper for the defendant to obtain a definition as clear as practicable of what the real Jones process is from one who is practically connected with it.)

A. Inasmuch as this question does not disclose any element of time for commingling, or whether the operation is a continuous one or not, I cannot state if it would be practicing this process.

X Q. 124. I will give you every element you call for, and repeat the question.

(Objection continued, and it is suggested that it is not necessary or to be expected that the witness should furnish the defendant's counsel the elements of the supposed construction or operation in order to make out a hypothetical case.)

(Question withdrawn, and restated as follows:)

X Q. 125. Considering the Jones process to be as stated in question 122, would you consider that it would be practiced if you poured a heat or tap from a blast furnace into a receiving vessel, whether it be heated or not, and subsequently poured other heats from the same or other blast furnaces into this vessel, so that the metal would mix and average in composition, and that time was given for commingling, and suitable converter charges less than the entire quantity of metal in the vessel were withdrawn from time to time from the vessel and refined in the converter?

(Objection after X Q. 123 continued.)

75 A. In the proposition stated, I would consider, inasmuch as it is not stated that this is a continuous operation, that this process is not practiced.

X Q. 126. If my question does not include a continuous operation, what do you mean by that expression?

(Objected to as incompetent.)

A. By continuous operation I mean one wherein this receiving vessel after being once filled is kept filled, or practically so, and in which the withdrawals are balanced by new charges, which in itself has the element of continuity provided for.

X Q. 127. With these additions to the proposition, would you consider the Jones process practiced in proceeding as set forth in X Q. 125?

A. I would, to the best of my judgment.

X Q. 127½. If the first claim of that patent omitted anything relating to the continuous operation, such as set forth in your answer 126, would you consider the process practiced if there were no replenishing after you commence to withdraw the metal from the vessel?

(Objected to, because the witness, as has already been stated, was only offered as a practical expert in the manufacture of iron and

steel, and being practically acquainted with the actual operations of the Jones process, and not for the purpose of explaining or interpreting the scope or limitations of the patent with which this witness has already stated he is unacquainted, and counsel for defendant is notified that if he pursues this course, he must be held to make the witness his own.)

(Question withdrawn.)

X Q. 128. Considering the Jones process in its broadest view to cover the equalizing of the composition of the crude metal by commingling or mixing together the liquid metal charge and
76 subsequently refining the mixed and equalized charge, without reference to replenishings of the charge in the vessel, would you consider this process to be practiced if you poured two or more heats or taps from the same or different blast furnaces into a receiving vessel, whether it be heated or not, so that the metal would mix and average in composition, and that time was given for commingling, and the metal subsequently refined in a converter?

(Question is objected to for the reason that it calls for a definition of the scope of the Jones process, and the witness is cautioned in his answer to state whether he gives his answer from actual experiment of the suggested operation or not. The witness is also requested to notice the fact that the question calls for a definition of the Jones process.)

(The continued objections made after each question, put evidently for the purpose of influencing the witness in his answers, are protested against. Defendant's counsel also protests against any instructions to the witness as to what he shall answer, as the witness is now under cross-examination and is presumably able to frame his own answers.)

A. Having been associated with the operation of the Jones process from its installation until quite recently, I would state from my knowledge of this process, that the proposition as stated is not the method by which the Jones process is conducted.

X Q. 129. Please answer the question put to you as it is your duty to do as a witness.

A. I have answered the question as I understand it.

X Q. 130. I confess I do not understand your answer to X Q. 128, whether it refers to my statement as to what the Jones process is, or whether it refers to the latter part of the question, wherein I ask you whether this process would be practiced. Explain this, and then answer X Q. 128 without reference to your supposed knowledge of the Jones process as practiced.

77 (Complainant's counsel objects that the very form of the question shows that the defendant's counsel is going beyond the limit of cross-examination, because his question excludes from the consideration of the witness the very thing as to the knowledge of which he is put on the stand as a witness. If the question calls for a mere hypothetical answer, without reference to the witness'

practical experience, the witness is instructed that he need not answer the question.)

A. My answer refers to the statement as to what the Jones process is, practiced as I am acquainted with it, but in order to answer X Q. 128 without reference to my knowledge of the Jones process as practiced, appears to me one rather for a patent expert, and with which matters I am not familiar.

X Q. 131. What part of X Q. 128 do you not understand?

A. I do not recall that I did not understand any of it.

X Q. 132. What part of Q. 128 do you say does not set forth the Jones process, and why?

(Defendant's counsel is requested to state what he means by the Jones process, whether he means the process described and claimed in the patent in suit, or the process which the witness has been acquainted with in actual operation, and because if it is the former, then he is asking the witness to interpret the patent as an expert.)

(Defendant's counsel replies that he means the Jones process as the witness has defined it, with the limitations referred to in X Q. 128, which the witness himself has requested.)

(Question objected to as an expert question.)

A. The Jones process, as I am familiar with it in practice, consists in replenishing the molten metal in order to make it a continuous operation, which is not included in the proposition presented.

78 X Q. 133. Do you think that the Jones process would be practiced without replenishing the metal?

(Objection continued.)

A. Your question appears to me to be one of expert patent testimony, with which I am not familiar, and I am only able to testify with respect to the Jones process as I know and have seen it practiced.

X Q. 134. Then you refuse, do you, to state anything in connection with the Jones process and what it is, outside of what you have actually seen?

A. I can only state the information I have in regard to the process by a practical knowledge of its operation.

X Q. 135. What is the ordinary amount of metal drawn from a cupola at one tap? I mean cupolas used for heating Bessemer metal.

A. I should judge about two tons.

X Q. 136. If you have, say four or five cupola furnaces, which you charge with different qualities of pig metal, and if you tap from these cupolas and run the metal into a common ladle, will the metal in that ladle mix so as to give uniformity of metal?

(Objected to as incompetent, and not proper cross-examination.)

A. If allowed a little time for commingling, it will give uniformity of metal.

X Q. 137. And if this was practiced continuously, and the metal run into the ladle, and charges of less than the amount of metal in that ladle were withdrawn therefrom from time to time, the ladle being thus replenished with fresh metal from the cupolas to keep up this supply, would the metal in the ladle intermingle so as to give uniformity of metal?

A. It would.

X Q. 138. What is your understanding of the term "molten metal"?

79 A. As I have used this term in my testimony, it has referred to the metal obtained from blast furnaces.

X Q. 139. Now take the natural meaning of the word which you as a skilled metallurgist would know, what is the meaning of the term "molten metal"?

A. To give you a definition, "molten metal" is simply the liquid form of any metal that will liquefy.

X Q. 140. Which, of course, includes metal in a cupola?

A. Certainly, but in practice the term used at the works, and of common acceptance, is "cupola metal," while that from the blast furnace is, by common acceptance at iron works, called "molten metal."

X Q. 141. When you were examined as a witness in the Maryland suit, you were asked in effect if part of the metal were taken from the mixer supplied with the metal from blast furnaces, and the remainder of the charge taken from the cupola, substantially the same advantages from the mixer would be obtained, and answered this question as I understand in the affirmative. Are you still of the same opinion?

A. I have no reason to change my views from what I stated in that testimony, and I further believe it to be a fact, according to the information given in subsequent testimony in that case. My answer to Q. 15 in that case is as follows:

"It would get precisely the advantages I have stated, inasmuch as the operation towards producing uniformity would be the same in the mixer as in the cupola. I can further explain, in their practice why the cupola was used, the reason therefor being that they erected and put in operation their blast-furnace department at a period earlier than their steel works, with the result that they accumulated a large amount of pig iron in their yards, and in order to get rid of this pig iron it was necessary to remelt it in a cupola, and while they used the cupola for producing a uniform metal for part of their charge, they used the mixer for producing like

80 uniformity in the other part of their charge. Their blast furnace being still in operation, it was more profitable to use all of their molten metal direct; the steel works requiring more iron than the number of furnaces in blast would supply, they utilized their stock of pig metal in the yard to make up the deficiency."

Adjourned to meet tomorrow, May 23, 1896, at 10.30 a. m.

PITTSBURG, *May* 23, 1896.

Met pursuant to adjournment.
Present, as before.

Examination of Mr. GAYLEY resumed:

X Q. 142. The answer which you had copied upon the record was the answer to Q. 15 of your direct examination in the Maryland case, which took place on June 6, 1895, was it not?

A. Yes.

X Q. 143. In looking over the analyses of the blast-furnace metal before pouring into the mixer, as set forth in your answer 9, I see several analyses of silicon contents above 2 per cent., the analysis in one case being 2.31 per cent. Would that percentage of silicon be too high to work without difficulty in converting the metal into Bessemer steel?

A. Metal of that composition would be worked with considerable loss and expenditure of time that in practical operation is not considered desirable. At the same time, I cannot say that it presents any difficulty.

X Q. 144. Well, in the practical operation of making Bessemer steel, where you have molten blast-furnace metal as high as 2¼ per cent., and known to be that high in silicon, what is your usual way of working it?

A. Our usual way of working it is to charge it into our metal mixer in order that it may be reduced in percentage of silicon by admixtures with other metals.

81 X Q. 145. In case the molten blast-furnace metal drawn from the metal mixer is as high as 2¼ per cent. in silicon content, what is your usual way of working it?

A. We have no usual way of working it, as the metal that I am acquainted with as passing through the mixer has very rarely ever been as high as 2 per cent., but in case it should be that high we would transport it to the Bessemer department and refine it in the usual way at the expenditure of time and loss of metal.

X Q. 146. Where you had molten blast-furnace metal of high percentage in silicon, such as 2¼ per cent. and over, before you employed the metal mixer, did you use any way to correct or lower the percentage of silicon in the converter charge?

A. We had no method of lowering the percentage of silicon in the charge before pouring it into the converter, and could only correct in part the excessive amounts by using large quantities of unmelted steel scrap in the converter itself.

X Q. 147. Did you ever employ this steel scrap in connection with the metal from the mixer?

A. We aim to run the silicon in the metal from the mixer at such a point that it will give us a slight margin of heat above that actually required for conversion, in order to utilize the small amount of scrap that is made from day to day in the converting mill.

X Q. 148. Then you do as a regular practice melt steel scrap in the converter in connection with the blast-furnace metal which is drawn from the metal mixer and introduced into the converter?

A. We do.

X Q. 149. Why do you not introduce the steel scrap into the metal mixer when you know the metal is high in silicon?

(Objected to, for the reason that the question is indefinite, and because it is based upon an assumption not warranted by the witness' testimony.)

82 (Defendant's counsel is pleased to see that he has been able to ask at least seven questions without objections by complainant's counsel.)

A. For the very best reason, namely, that the temperature of the metal *is* a metal mixer, even fresh from the blast furnace, is so much lower than the temperature of the metal in the converter that it would not melt, the scrap in the converter not melting if charged at the beginning of the operation until the temperature is raised by the combustion of the metal to a sufficiently high point.

X Q. 150. When you thus melt the scrap in the converter, about how long does it require to bring it to molten condition after you start the blast?

A. As that depends on the size of the pieces of scrap and the composition of the molten metal charge, I cannot determine.

X Q. 151. Well, after the scrap is melted, I presume it becomes diffused within the molten blast-furnace metal and so produces the reduction in percentage of silicon. Is that correct?

(Objected to, for the reason that the witness has not stated that the ordinary use of scrap is for the purpose of reducing silicon, and the question is therefore, as yet, unwarranted.)

(Defendant's counsel calls attention to the fact that the question is based on a presumption, and suggests that complainant's counsel reads the question before objecting, and do not attempt to instruct the witness, who is evidently well able to take care of himself.)

A. The scrap after melting becomes diffused with the metal that was brought from the blast furnaces, and produces a reduction in the percentage of the silicon.

X Q. 152. Well, when you have a blast-furnace metal known to contain too high a percentage of silicon, and you employ for
83 your metal mixer a heated furnace chamber, you would produce practically the same result by introducing your scrap or a low silicon pig into your heated furnace chamber, would you not?

(Objected to, for the reason that the question appears to be indefinite and hypothetical, there having been no statement in the evidence-in-chief that such a device or method as spoken of in the question has ever existed or been in use.)

(Defendant's counsel has a higher opinion of the witness' ability to understand the English language and of his knowledge of metallurgy, than to think he cannot understand the question.)

A. Such a result would be impossible.

X Q. 153. Are you willing to stake your standing as a metallurgist on your last answer?

(Objected to, for the reason that the Q. 152 is indefinite.)

A. Inasmuch as the question is a metallurgical jumble, my answer thereto is correct, and on that I stand.

X Q. 154. I presume you have knowledge of what an ordinary Siemens open-hearth furnace is, or what a reverberatory puddling furnace is?

A. I have nothing to do, as far as my purpose as a witness consists, in knowing anything except what the Jones metal mixer is, and the processes used in connection with it.

X Q. 155. Such may be the instructions given you by counsel for complainant, but the court will instruct you to answer the questions put to you and answer them directly. Please answer my last question.

(Counsel for complainant states that he has given no instructions to the witness whatever, and that the statement of counsel for respondent is unwarranted and unprofessional.)

(As a warrant for this statement in the question, defendant's counsel calls attention to the numerous objections on cross-examination of the witness, and submits to the court whether complainant's counsel was wise in using such terms.)

84 A. I have seen such furnaces.

X Q. 156. Do you mean that it would be impossible in such furnace to introduce blast-furnace metal known to contain too high a percentage of silicon, and to introduce into the metal steel scrap or low silicon pig, and melt down the scrap or pig and cause the same to reduce the percentage of silicon?

(Complainant's counsel objects to the question as improper cross-examination, and states in answer to defendant's counsel that if he chooses to use this witness as his expert, he has a right to do so, taking the consequences of so doing, but that otherwise complainant's counsel objects to a general examination as to the whole art of the manufacture of steel not in this case and utterly uncalled for, and desires this objection to apply to all further cross-examination of this character.)

(Defendant's counsel states that his entire examination has been based upon the direct examination and matters germane thereto, that this and like questions are clearly proper on cross-examination in view of the extended examination on the direct examination as to the history of the art. He refuses to take the witness as his own, and he hopes that complainant's counsel will not consider it to interfere further in view of the fact that he has continued his objections to the entire line of examination.)

A. The percentage of silicon could be reduced, but the operation would not be such as that which is indicated in a Bessemer converter.

X Q. 157. And the same result as to reduction of silicon would

be obtained if low silicon cupola metal were introduced into the furnace or receiving vessel, whichever was used, the cupola metal commingling with the blast-furnace metal, would it not?

A. The same result as what?

85 X Q. 158. The same result as set forth in Q. 156, where the scrap or pig causes a reduction of the percentage of silicon in the blast-furnace metal?

A. It would, and it would not; if introduced in comparison with low silicon pig it would, but not the same as the scrap. I am assuming that the same quantity of metal is used in each and every case, and that the same results are expected.

X Q. 159. I presume I might have said like results as to the reduction of silicon. Will you now please state whether or not, if you introduce molten low silicon cupola metal into a furnace, or a receiving vessel, containing high silicon blast-furnace metal, you will not obtain a reduction of silicon throughout the mass by the commingling of the one metal with the other?

A. Yes, if given sufficient time for commingling, the results will be as stated.

X Q. 160. In order to produce the best results for the preparation of the metal for conversion into steel, I presume that the percentage of silicon in the blast furnace metal and in the cupola metal respectively should be approximately more?

A. It should.

X Q. 161. I presume, from your testimony, that you belive the so-called metal mixer to be the most practicable way of obtaining blast-furnace metal having a uniform and approximately known percentage of silicon. Is this correct?

A. It is.

X Q. 162. Is it not also the fact that the most practicable way of obtaining the molten cupola metal, having a uniform and approximately known percentage of silicon, is to tap the same from a number of cupola furnaces into a receiving ladle so as to permit it to commingle, and tap the cupola metal from this ladle?

A. That is the best method to obtain those results.

86 (Defendant's counsel notes upon the record that the cross-examination is closed, except that he desires an answer to his request for the yearly product of Bessemer steel of the complainant company during the years 1882 to 1887, in accordance with his request after the answer to cross-question 82. If the witness is not ready now to furnish this, he has no objection to counsel proceeding with the redirect examination, the information — be furnished at a later date.)

(Complainant's counsel replies that as it is not within the power of the witness to give the information desired, and as he has no control of the records of the company to furnish such information, they (complainant's counsel) state that if defendant's counsel will make a request in writing to them stating what information he desires in regard to the question put to Mr. Gayley, they will endeavor to secure it for him and furnish it at another period, as it is

impossible to do so today, with the understanding that the cross-examination of the witness is now closed.)

(Defendant's counsel repeats his request for a yearly product of Bessemer steel of the complainant company during the years 1882 to 1887, so placing it in writing as requested by complainant's counsel. He has no objection to the cross-examination being considered closed, but desires that his request be complied with before the closing of complainant's examination-in-chief.)

(Complainant's counsel deny the right of defendant's counsel to make the inquiry which he has stated, as the product was not that in any way of the process of the patent in suit; nevertheless he is willing to have the statement made and produce it as part of the cross-examination at some time before the defendant commences its proofs in this case.)

(Defendant's counsel thinks this should be furnished before the closing of complainant's case in chief.)

87 Redirect examination by Mr. BAKEWELL:

R. D. Q. 163. In your last answer on cross-examination you have stated that the method stated in the question is the best method to "obtain those results." Will you please to explain further what you understood by the question and what you meant by your answer?

A. By the "best method," I mean that whereas a cupola generally furnishes but two tons of iron at a single tap, and inasmuch as the converter charge consists of 8 to 14 tons, it is a better method to tap at the same time from a number of cupola furnaces to get this quantity of metal, rather than to tap the cupolas alternately. I considered in my answer that the metal running from each cupola had a uniform and known percentage of silicon, and further that the making of metal of a uniform and of approximately known composition is not obtained, nor is it required by a commingling of the metal after being tapped, but this uniformity in composition is obtained from each cupola by the mixing of the metals before they are charged into the cupola, and this is an essential feature of the cupola operation as constantly practiced.

R. D. Q. 164. In your direct and cross-examination in this case, three processes have been mentioned as being used in Bessemer steel works, that is in the practice of the converter process, namely, the cupola process, the direct process, and the mixer process. Will you please state as concisely as possible the differences between these several methods or processes, indicating the function performed by the apparatus used in each process, and the result obtained therefrom.

(Objected to as not proper redirect examination, the witness having been fully interrogated as to these matters, and having pointed out the supposed differences in his direct or opening testimony. This objection is continued without notice to any further questions of like character.

88 Complainant's counsel replies that the question put to the witness is only rendered necessary by the fact that defendant's counsel on cross-examination has gone entirely outside of the direct process, and examined particularly as to the supposed result of the cupola process, which has rendered it important to have the matter fully explained to the court.

Defendant's counsel calls the court's attention especially to answers 6 and 11 of the direct examination.)

A. I will first explain briefly the process by which the metal is obtained for the different purposes as indicated. The cupola is an apparatus used for the melting of pig iron with the use of solid fuel, into which is charged a mixture of pig iron taken from different piles, each pile of a definite composition, and which being melted, with a small but definite loss, yields a molten metal of definite chemical composition. Such composition is determinable before the material is charged into the cupola. The blast furnace is an apparatus for the extraction of iron from its ore with the aid of solid fuel by first reducing and then melting it, into which is charged a mixture of ores taken from various piles of less definite composition than the metal used for the cupola by reason of the moisture that the ore absorbs. The iron in this ore is reduced and melted with a large but indefinite gain of carbon, silicon, etc., and thereby produces a product of indefinite composition.

Now as to the purposes for which the appliances, treating metals as described, are used. The cupola assembles the ununiform products of the blast furnace in a cold and solidified state, and makes them uniform by remelting. The metal mixer assembles the ununiform products of a blast furnace in a hot or molten state and makes them uniform by commingling together. In each of these cases, the metal is delivered from the cupola or metal mixer to a Bessemer converter.

89 Next, the direct-metal process consists in delivering the ununiform products of a blast furnace to the Bessemer converter without any change in the composition and directly without the aid of a mixer. In this process, ladles from one furnace have been attempted to be made uniform by mixing half and half with the iron from another furnace, but this has not been found satisfactory nor practicable, and this is the only manner of trying to produce uniform metal by the so-called direct process that has been attempted.

Lastly, as to the appliances for carrying on these processes. In the cupola practice a number of cupolas are constructed close to the Bessemer converter and in line with the track, the molten metal running in spouts from these cupolas to a single ladle, which is called the iron ladle or charging ladle, and this ladle is moved along the track to discharge its contents into the Bessemer converter. It is customary not to drain all of the metal out of this ladle, weighing scales being provided in front of the converter so that the exact amount of metal may be poured in.

In the mixer process, a large number of ladles are provided to transport the iron in a molten state from the blast furnaces to the

metal mixer, into which it is poured, and another large number of ladles are further used for transporting the metal from the metal mixer to the converter. The amount of the metal poured out of the mixer is determined by a scale placed on that side of the mixer. This metal mixer is a large receptacle of any shape, lined throughout with refractory material, and as now constructed, in capacity of from 100 to 300 tons, from which iron is being constantly withdrawn for use in the Bessemer converter, and likewise the body of iron is being constantly replenished and made a continuous operation, and this process of the metal mixer produces a uniformity of metal without the expense and waste of the cupola.

The direct-metal process requires a large number of ladles
90 which transport the molten metal directly from the blast furnaces to the Bessemer converter, there being in this process no opportunity for making the metal uniform in composition, or of uniform weight.

R. D. Q. 165. Then am I to understand that in these processes named the essential differences are, that in the cupola process the metal is mixed and a uniform quality secured before it is put into the cupola and remelted, and that in the direct process no mixture or selection of metals is possible, and that in the mixer process the metal is mixed in a molten condition, and thereby uniformly secured?

A. The essential differences are as stated in the question, and I would explain further that while we know the composition of the metal which enters into the cupola, in the mixer process, by reason of handling hot metal, we have no time to make analysis, cannot know its composition, and for this reason it is necessary to work with large quantities of metal.

It is hereby admitted by defendant's counsel that on or about October 23, 1895, a notice was sent by complainant's counsel to the Cambria Iron Co., at their office in Philadelphia, referring them to the patent in suit, and alleging that they were infringing the same, or preparing to infringe the same.

The witness, James Gayley, having been requested to ascertain the date on which he visited the works of the Cambria Iron Company as stated in his examination-in-chief, now states as part of his testimony herein, that he has examined his diary and finds an entry therein that the visit referred to was made on November 1, 1895.

JAMES GAYLEY.

Counsel for complainant offers in evidence the report of the Commissioner of Patents to Congress, for the year ending December 31,
1895, referring specially to pages 1004 and 1023 of the Official
91 Gazette of the U. S. Patent Office, vol. 75. It is marked "Complainant's Exhibit Commissioner's Report."

(Objected to as immaterial.)

Counsel for complainant also offers a certified copy from the recorder's office of Allegheny county, Pennsylvania, of the certificate and articles of association of the limited partnership of the Carnegie

Steel Company, Limited, changing the name of the partnership association of Carnegie Brothers & Company Limited to the Carnegie Steel Company Limited, and increasing the capital stock thereof; and it is marked "Complainant's Exhibit Limited Partnership Certificate."

MAY 27, 1896.

Met pursuant to adjournment.

Present: Counsel as before.

(Defendant's counsel here objects to the last exhibit offered, to wit: "Exhibit Limited Partnership Certificate," as not proving title in complainant.)

Testimony of Levi T. Upton.

LEVI T. UPTON, a witness called on part of complainant being duly sworn, testifies to questions put to him by counsel for complainant, as follows:

Q. 1. State your name, age, residence and occupation.

A. Age, 42; residence, Duquesne, Pa.; occupation, manufacturer of Bessemer steel; name, Levi T. Upton.

Q. 2. How long have you been engaged in the manufacture of Bessemer steel?

A. I have been working at the making of Bessemer steel for 20 years, in different positions.

Q. 3. Have you ever visited the Bessemer plant of the Cambria Iron Co., at Johnstown?

A. Yes, sir.

Q. 4. Do you know whether or not they have been using at that plant what is known as the direct process?

92 A. Yes, sir.

Q. 5. At that plant when they tap the metal from the blast furnaces, where do they take it to?

A. Take it to a mixer.

Q. 6. What is this mixer you speak of?

A. It is a large vessel holding 300 tons of molten metal. It is supposed to hold 300 tons when it is full.

Q. 7. Is this mixer a stationary vessel?

(Objected to as immaterial.)

A. No, sir.

Q. 8. Please describe the mixer at the Cambria Iron Company's plant.

A. The square of the mixer inside the lining I am told is 18 feet, cylinder shape, rotated by hydraulic pressure.

Q. 9. How is the molten metal brought from the blast furnaces to the mixer?

A. On a wide-gage track on ladles.

Q. 10. How is it transferred from the ladle to the mixer?

A. The ladle is carried up about a distance of 30 feet by hydraulic lift, and poured from there into the mixer.

Q. 11. How is it poured into the ladle from the mixer?

A. By a stationary engine to the ladle.

Q. 12. What is done with the molten metal in the mixer, what use is it put to?

A. It is drawn from there into a ladle and carried to the Bessemer converter.

Q. 13. How is the molten metal transferred from the mixer to the ladle? Please make your answers a little fuller.

A. The mixer is rotated to fill the ladle which carries the molten metal to the converter.

Q. 14. Am I to understand you that the mixture is tilted so as to pour the molten metal into the ladle?

93 (Defendant's counsel in view of the particularity of this question as to the tilting of the mixer, inquires of complainant's counsel as to whether such tilting is a necessary part of the supposed Jones process.)

(Counsel for complainant states that the witness is called merely for the purpose of proving the method in use at the plant of the Cambria Iron Company, and the question put to the witness is for the purpose of bringing out the exact operation of the method at respondent's works. The question asked by counsel for defendant is therefore immaterial, so far as the testimony of this witness is concerned.)

(Defendant's counsel notes that the question is not answered.)

(Counsel for complainant does not consider himself to be on the witness stand.)

A. Yes, sir.

Q. 15. Please describe fully the operation of the mixer at the works of the Cambria Iron Company.

A. Well, I saw them take the blast-furnace iron from the scales, I did not go further to see where the iron come from, the scales were those used for weighing the iron as it came from the blast furnace, as I understood. I saw them run it up on the elevator and pour it into the mixer, which contained at that time about 175 tons of molten iron from the furnaces. It was then poured out into a ladle on the opposite side, from there carried to the Bessemer converter and worked in the usual way.

Q. 16. About how much metal, that is molten metal from the blast furnaces, did you see put in the mixer in the period of time you were there observing it? And state how long this period was.

94 A. I was on the mixer floor about a half an hour, and in that time saw two ladles poured each containing I suppose from 12 to 18 tons, I didn't inquire the size of the ladle. But in my judgment, that is about what they would hold.

Q. 17. Did you see any metal drawn from the mixer to be taken to the converters? If so, in what amounts?

A. I asked what sized heats they were running; they told me 11½ to 12 ton, and half of that was supposed to be mixer iron, the other half being from the cupolas.

Q. 18. Whom did you ask this question?

A. Mr. Parker, superintendent of the converting works.

Q. 19. Do you know from how many blast furnaces the metal was being taken to the mixer?

(Objected to for the reason that the witness cannot know in view of his answer 15, as he only saw the metal on the scale, and "did not go further to see where the iron come from." The question can therefore only call for hearsay evidence.)

The witness is requested to answer the question without regard to the objection. Defendant's objection was addressed to the court and not to the witness.

A. I do not know how many furnaces they run to the mixer, but they told me their best furnace, No. 5 without a blast. I believe they have six furnaces.

Q. 20. Who told you this?

(Hearsay evidence is objected — wherever it is asked for.)

A. Mr. Cabbit, I believe is the man's name, and he is superintendent of the furnaces.

Q. 21. Did you see any mark upon the mixer, and if so, was your attention called to it in any way?

A. My attention was called to a chalk mark, which, by the way, I had noticed before, on the side of the mixer. They told me that they didn't allow them to run that chalk mark below the floor. When it came to the floor they still had retained in the mixer about 175 tons.

95 Q. 22. Please state what you mean by the chalk mark coming to the floor.

A. What they call the mixer floor is where the men work to rotate or tilt the mixer, and if the mark they have on the mixer goes below the floor out of sight, they cannot tell how much they have left.

Q. 23. Am I to understand you that the mixer was not to be tilted more than enough to bring the chalk mark on a level with the mixer floor?

(Objected to as leading.)

A. That is the meaning I wish to convey, and if they hadn't enough to make out their heat without going below the floor, they wait till they get more in.

Q. 24. Who explained this to you?

A. The superintendent of the Bessemer department.

Q. 25. What is his name?

A. C. F. Parker.

Q. 26. I understand, then, that if the chalk mark did not go below the level of the mixer floor there would be 175 tons of molten metal retained in the mixer. Is this correct?

A. Yes, sir.

Q. 27. When you were at the Cambria works did you notice any blast furnaces in operation?

A. Yes, I did.

Q. 28. How many blast furnaces did you see in operation?

A. I believe I only noticed one, but I am satisfied there were more.

(It is noted on the record by defendant's counsel that the satisfaction of the witness is not evidence.)

(Counsel for complainant desires to be informed whether counsel for respondent desires to deny the accuracy of his admission already made on the record that the metal fed to the mixer was from two or more blast furnaces.)

96 (Defendant's counsel answers frankly no, but in view of his free admission of the practice followed by the defendant's company as found after answer 34 of the deposition of the witness Gayley, he is at a loss to know why this witness has been examined and time consumed in connection with him, unless complainants expected to refuse to use the admission, so freely given; and it is for this reason, because he is entirely at a loss to understand the course followed, that he has taken so-called technical objection to the deposition of this witness, thinking it necessary to protect his client in every way.)

(Counsel for complainant here states that the reason for examining this witness, and perhaps other witnesses who are yet to be examined, is to supply the incompleteness of the admission made by counsel for respondent, and that if counsel for respondent is willing to supply the facts in regard to the size of the mixer, the amounts of metal daily added thereto and removed therefrom according to the ordinary practice and the amount of metal usually retained in the mixer, there will be no further need of taking testimony in regard to these points.)

(In answer to the last statement of complainant's counsel, defendant's counsel states that they are now and always have been ready and willing to give all information in regard to the operation of their plant which can be at all relevant in this case; that they freely furnished blue prints of their plants, part of which were rejected by the complainant counsel; that seeing that the witness Gayley failed to prove infringement, they made a free admission on the record of everything which they supposed necessary to give to the complainants proof of infringement, and that instead of calling attention to any supposed incompleteness thereof, complainant's counsel satisfied themselves with objecting to part of it for other reasons; that before this witness was placed on the stand

97 today, when their attention was called to the supposed incompleteness, defendant's counsel offered to stipulate as to these facts, but complainant's counsel would not receive the stipulation, unless it contained further stipulations as to the procedure in the case after the complainant had closed *their* testimony, and which defendant's counsel did not feel was reasonable to ask.)

(Defendants are now ready to admit what they actually do in the operation of their plant so as to supply the supposed incompleteness of the former admission.)

(In view of defendant's statement, the following stipulation is now placed upon the record:)

Stipulation.

As defendant's counsel is expecting to sail for Europe in a few days and may not be back for about four months, it is therefore stipulated by the counsel for both parties in order to save delay, as follows:

That the defendant in this case has used the mixer and other apparatus shown in blue prints, Complainant's Exhibits Nos. 1 and 2 of defendant's mixer, together with blast furnaces at Johnstown, Pa., since a date prior to the commencement of this suit, and at various times since that date, in the manner following; that is to say, the molten pig metal has been tapped from the several blast furnaces, four or five in number, and poured into the mixer, which has an actual capacity of about two hundred and eighty tons, additions to this molten metal from the blast furnaces being made from time to time to the mixer in quantities of about fifteen tons as it is tapped from the blast furnaces; and that the molten metal in the mixer has been discharged by tipping the mixer from time to time, and as required for charging the Bessemer converters, into ladles having a capacity of about fifteen to eighteen tons each; the charges withdrawn being from about eleven to twelve tons each; that the amount of molten metal in said mixer varies from nothing
98 to its full capacity, depending on the supply and demand, the supply being generally sufficient to keep the mixer more than half full of molten metal, which metal remains molten therein; that the molten contents of the mixer are drawn off from time to time as required for the converters, the converter charges being from eleven to twelve tons each, as above stated; the metal being charged into the converters in a molten condition; and sometimes a smaller portion being withdrawn from the mixer, and the remainder of the molten metal for the charge being run into the ladle containing the mixer metal from cupolas forming part of the converter plant, the combined charge of mixer metal and cupola metal being introduced into the converters and refined in the usual manner.

(In view of the above stipulation the testimony of the witness, Upton, now on the stand, is considered completed, there being no cross-examination, the witness now signing his deposition.)

LEVI T. UPTON.

PITTSBURG, *May* 28, 1896.

Met pursuant to adjournment.

Present, as before.

Testimony of George Lauder.

GEORGE LAUDER, a witness produced on behalf of the complainant, being first duly sworn, says as follows in answer to questions by Mr. Bakewell:

Q. 1. State your name, age, residence and occupation.

A. George Lauder; age, 59 years; residence, Pittsburg, Pa.; occupation, member of the firm of Carnegie Steel Company.

Q. 2. Please state the history of the introduction and use of the Jones metal-mixing method, as you have used it at the Edgar Thomson works.

A. I will give a general outline of the history and operation of the Edgar Thomson works. The works were started about
99 the year 1876 with what we called the cupola process for supplying metal to the converters. This process was used exclusively until about the year 1882. At this date we introduced what we called the direct process. This process consisted in using the molten metal direct from the blast furnaces, conveying it to the converters. This process was run in connection with the cupolas until the year 1887. At that date we commenced the use of the mixer process. This process has been in use ever since, and is still at work. For some time after its introduction it was used in connection with the cupolas. During the whole period of use of the direct process we had a great deal of trouble on account of the number of defective rails we made and the irregularity in quality of the first quality of rails we sent out. At times this reached such alarming proportions that we frequently discussed the question whether it would not be advisable to return to the cupola practice. The only alleviation we had during that time was to use more cupola metal whenever the furnaces went off. The introduction of the mixer cured this matter completely. For some time after the introduction of the mixer the cupolas were continued in use. This was more on account of a want of confidence in the mixer than any other cause. This was shown by the entire stoppage of the cupolas and their ultimate removal. I should mention in this connection that cupolas had been erected recently at the Edgar Thomson works, but the difference is that while formerly the cupolas were used to aid the mixer, now the mixer is used to aid the cupolas, the cupolas now being used entirely to melt scrap, and occasionally "off" metal, that is, metal not quite fit for the Bessemer converter alone; by using it in small quantities with the mixer metal we can get rid of a lot of metal that would otherwise be a loss.

Prior to the year 1887, and for some years subsequently, it was part of my particular duties to be in continual communication with
Capt. Jones regarding the operation of the steel works. The
100 question of adopting the mixer was brought up frequently before it was decided to experiment. I recollect distinctly that I opposed it strenuously. I asked if any one had ever done it before, not only Capt. Jones, but from almost anybody that I thought I could get information from. The answers were uniformly in the negative. For this reason I kept up my opposition to the experiment, on the ground that it was too much of an experiment altogether for us as manufacturers to meddle with. It was only after continued and urgent representations that I acquiesced in the experiments we made. The experiment was then made, proved entirely successful, and instead of a large vessel being built, we decided to duplicate the experimental vessel, which was, roughly speaking, 100 tons capacity.

Q. 3. Describe the cupola process, the direct process, and the mixer process, as used at the Edgar Thomson works.

A. The cupolas are furnaces, the function of which is to melt cold pig metal. The usual arrangement in Bessemer steel plants is to place a number of these cupola furnaces behind the converters, but contiguous to them. The metal after being melted is run into a large ladle, commonly called the charging ladle. This ladle is made of sufficient capacity to hold somewhat more than a converter charge. After receiving the molten metal from the cupolas, it is moved along a track in front of the converter to be charged, and the molten metal is poured from it into the converter, scales being provided so that a given weight is measured out. In this way, the ladle is never entirely emptied, and a fixed charge always secured. In the cupola practice, care is always taken to select metal suitable for conversion.

The direct process consists of running molten metal in ladles direct from the blast furnaces to the converters. As practiced at the Edgar Thomson works, there was more or less irregularity in the weight of the charge, and so much irregularity in the quality of the metal that it gave us all the trouble and anxiety which
101 I have before mentioned. Commercially the saving was made in not having to remelt cold metal in the cupolas, but as I indicated before, there was a difference of opinion between the members of the firm whether this saving was not counterbalanced by the losses from defective product.

The mixer process consists essentially, as practiced at the Edgar Thomson works, of placing a large vessel at any convenient position between the blast furnaces and the converters. A number of ladles are provided to carry molten metal from the blast furnaces to the mixer. The metal is poured into the mixer and then poured out. The ladles receiving the mixer metal stand on scales, and a given weight is put in every charge. In bringing the metal to the mixer care is taken to have metal from as many different furnaces as possible poured in successively, the object being to obtain a uniform metal. A concise way of stating the difference between the three processes mentioned would be to note the different tools used in operating them. In the cupola process, only one ladle is used; in the direct process, one set of ladles is used, necessarily consisting of a considerable number of ladles; in the mixer process, two sets of ladles are used, one set to bring the metal to the mixer, the second set to take it away from the mixer. In works more recently constructed this second set of ladles is reduced to one, which is naturally the charging ladle as used in the cupola practice, the mixer being placed contiguous to the converter.

Q. 4. Please state the quantities or amount of metal usually fed to the mixer at one time, the amount removed from the mixer at one time, and whether or not any metal is usually retained in the mixer; also state the amount of metal usually kept in the mixer, referring to the practice at the Edgar Thomson works.

A. I am not very familiar with the details nowadays. It is now some years since I gave any attention to the practical operation at

the works. To the best of my knowledge, the metal is car-
102 ried to the mixer in 15 to 16 ton lots, and taken away in about the same amount; the general operation of the mixer is, as it has always been, to keep it as nearly full as possible.

Q. 5. What steps were taken by The Carnegie Steel Company, complainant in this suit, towards securing the right to use the Jones imxer process, and what was done toward introducing it into use in Europe?

(All evidence relating in any way to introduction of the supposed process in Europe, or in any country outside of the United States, is objected to as inadmissible, and also as irrelevant and immaterial, this objection being continued to this line of examination without further notice.)

(Counsel for complainant answer that the evidence which will be produced is perfectly competent to show the utility of the invention and the recognition of its utility by the art.)

(The objection made is insisted upon, and the question is further objected to as compelling these defendants, in order to rebut any such inadmissible testimony, to take testimony abroad at great expense to the defendants, and it is suggested to complainant's counsel that before proceeding with this line of examination, he submit the matter to the court whether it is admissible.)

A. After we found the mixer so successful we arranged with Capt. Jones that he should apply for patents. The arrangement was that in consideration of our receiving a shop right and one-half interest in all the foreign patents, we were to bear all the expenses of the experiment and all the costs incurred in securing patents. Patents were applied for and granted in the United States, England, France, Belgium and Germany, to the best of my recollection. Subsequently Capt. Jones asked me how the firm would feel about buying his entire interest in the patents. I said to him I
103 would talk it over with my partners. I did this, and an arrangement was concluded by which we became the entire owners of all the patents on a payment of $35,000. This was consummated by Mrs. Jones, Capt. Jones having unfortunately met with a fatal accident before the papers were signed. I had several interviews with different parties in England regarding the introduction of the mixer process in Europe, principally with Mr. David Evans, at that time general manager of the Barrow steel works. Mr. Evans had taken sufficient interest in the process to send his son to the Edgar Thomson works to report on the action of the mixer. We made a special arrangement with Mr. Evans under which he erected a mixer at his works. I have seen this in operation, it proved entirely successful and the negotiations ended by a sale, to what I term the Evans syndicate, of the entire European patents for the sum of ten thousand pounds. The sale was made to Mr. Evans' son, and was concluded in Rome in the year 1891. I may add that I have seen the mixer at work in Germany in Hoerde works.

Q. 6. Can you state whether or not you have found the mixer process advantageous at the Edgar Thomson works?

A. We have found it highly advantageous, both in respect to saving money and saving the anxiety we had while using the direct process. The consensus of opinion has been throughout so pronounced regarding the benefit of this process—I may add its novelty—that I am surprised to find any adverse criticisms now tending to deprive Capt. Jones of the credit so justly due him after he is dead and gone.

Q. 7. What experience have you had, or how many years experience have you had, in the manufacture of steel?

A. In the manufacture and use of steel, since I started to learn my business, at 14 years of age—45 years.

Q. 8. Defendant's counsel having asked for a statement of the output of the Bessemer department at the Edgar Thompson
104 works between the years 1882 and 1887, the witness is asked whether he can produce such statement?

A. I produce the statement I now hand you. In the left-hand column opposite the years marked is the tonnage of ingots produced in that year. In the right-hand column is the tonnage of metal to produce those ingots. It will be noticed that up to the year 1887 the ingots are considerably in excess of the metal supplied to produce them. This is accounted for by the amount of scrap used and added to the converter, technically called "scrapping." In later years it will be noticed this difference diminishes, until in 1892 the metal is in excess of the ingots. This indicates nearly the entire cessation of scrapping; the scrap being more valuable than pig metal, we had thus an incidental saving from the use of the mixer.

Q. 9. To what is the absence of "scrapping" in later years due, that is, what was it that enabled you to do without the addition of scrap metal?"

A. The more regular composition of the metal enabled us to work much closer.

Q. 10. Was there any change in process in the year 1888, by means of which the "scrapping" was lessened?

A. No change.

Q. 11. Was it not in 1888 that you first commenced to use the Jones mixer?

A. Yes, that is the first complete year.

Q. 12 Was the lessening of using scrap due to the use of the Jones mixer?

A. Distinctly, it was the cause.

Counsel for complainant offers in evidence the statement furnished by the witness and asks the examiner to copy the same on the record.

105 *Statement.*

Year.	Ingots. Tons.	Molten metal. Tons.
1882	170,716	134,960
1883	189,684	163,444
1884	168,579	137,697
1885	163,251	143,946
1886	220,627	168,442
1887	241,875	191,560
Total	1,154,732	940,049
1888 (4 mos. out)	183,315	176,707
1889	336,004	316,936
1890	404,527	382,835
1891	324,937	317,590
1892	427,355	433,004
1893	314,659	325,525
1894	339,129	344,514
1895	459,018	469,288
1896 (4 months)	153,779	153,212
Total	2,942,723	2,919,611

Cross-examination by Mr. KAY:

X Q. 13. When you used what you called the direct process at the Edgar Thomson works, about what was the capacity of the ladles carrying the metal between the blast furnaces and the converters?

A. I do not recollect, but I will furnish the exact capacity from the records.

X Q. 14. What was the converter charge at that time from 1882 to 1887?

A. We have changed our converters at Edgar Thomson more than once, I think, so that I would require to go back to the records to be sure.

X Q. 15. You haven't any recollection of it yourself?

106 A. None that I could be at all sure of.

X Q. 16. Did these ladles carrying the metal directly from the blast furnaces to the converters have weighing apparatus connected with them?

A. I would state, generally, in answer to these questions, that I had nothing to do with the operation of the works at any time, except in consultation with Capt. Jones, who was superintendent. I have no knowledge of any weighing arrangement in use while we used the direct process. My recollection is there was considerable trouble on account of the irregularity in the amount of the charges sent to the converter.

X Q. 17. Do you know the capacity of the cupola ladle which,

according to your testimony, received the metal from several cupolas and charged it into the converter?

A. I do not recollect.

X Q. 18. Well, we will discuss this subject while we are at it. Am I right in understanding that your testimony as to the use of this cupola ladle in connection with a number of cupolas relates to a use of the same prior to 1882, and then, during the time that you were running what you call the direct process, from 1882 to 1887, and for some time after, you used what you call the mixer process?

(Objected to as immaterial, it not appearing that the use of the ladle in the cupola process, as testified to by the witness, is any different from that practiced long prior to 1882.)

(Mr. Kay suggests that this is the question for testimony and that he is questioning the witness in order to find out such facts.)

A. In my testimony I did not describe any ladle particularly in connection with the cupola process in use at the Edgar Thomson —. I do not recollect at all any of the details connected with the charging ladle in connection with the cupolas. It was never brought to my attention as a member of the firm.

107 X Q. 19. Haven't you any recollection at all on that subject as to the use of the charging ladle in connection with the cupolas?

(Objected to as indefinite.)

(Mr. Kay is trying to find something definite out of this witness, and that is why he asks the question.)

A. I thought I had made it perfectly clear that I never had any experience in the details connected with the running of the works. I had quite enough to do to attend to the general scope of the steel company and its various allied concerns.

X Q. 20. Then your knowledge on the subject of the manufacture of steel at the Edgar Thomson works was obtained by communication with Capt. Jones, or with the other superintendents following him, and not from direct actual experience. Is this correct?

A. My knowledge of the manufacture of steel, like all the other knowledge I have, was obtained by the closest observation I was capable of, and I visited the various works of our firm and studied their operations minutely for a great many years. I do not think it necessary to go into any lengthened statement concerning my knowledge of the manufacture of steel. The success of the Carnegie Steel Company, which is a matter of common knowledge in this district, is probably the best answer to the question.

X Q. 21. Well, it was because of your apparent absence of knowledge, at least of details, that I asked the question. As there are certain matters which we believe to be relevant and of importance as to the operation of these works that we should like to know, I will, at least, request you to obtain the knowledge from the records called for in my cross-examination, and be ready to report in regard to the same after lunch.

(Objected to for the reason that counsel for respondent's
108 questions, since and including cross-question 18, are utterly obscure and indefinite, and with an evident purpose of confusing the witness.)

A. I would much prefer putting a man on the stand who can give all this information desired definitely from his own knowledge. I am sorry I cannot make it clear what my particular function was in the operations of our company. Probably if counsel would bring to his mind the necessity for division of labor in a large concern, he could realize it.

X Q. 22. You referred in your answer 2 to the use of cupolas for melting "scrap," and occasionally "off" metal. What was the difficulty with this "off" metal?

A. Generally speaking, the metal did not contain the proper proportion of constituents to be used in the converter alone.

X Q. 23. What constituents do you refer to?

A. Probably, an excess or not enough of silicon, or an excess of sulphur.

X Q. 24. Do you mean such an excess of silicon that you would not put the molten metal into the mixer?

A. Probably, that might be, or it might be from a furnace that was not being used in connection with the mixer; in this case it would be metal there would be a difficulty in selling.

X Q. 25. Well, how would you be able to determine that this "off" metal was too high in silicon to be put into the mixer?

A. I will have to answer that like the other questions, in a general way; I never gave any attention to the details of selecting metals.

X Q. 26. Do you know enough to inform me whether, at the Edgar Thomson works, they had some way of determining whether the molten metal coming from the blast furnace was too high in silicon or sulphur to be poured into the mixer, so that in case it was, this metal could be cast into pigs?

109 A. At the time I was visiting the works regularly, I was cognizant of a process by which silicon could be determined within half an hour. We relied on the general working of the furnace, that is, the appearance of the slag, to judge whether there was too much silicon or not, and withheld or put the metal in the mixer accordingly.

X Q. 27. Why did you not put this metal in the mixer so that it could intermingle with the charges from other furnaces low in silicon or sulphur?

A. Because it is more economical to do it in the way I indicate.

Recess until 2 o'clock.

Witness makes the following statement:

Referring to my answer to X Q. 16, I recall that there was no weighing apparatus attached to the ladles referred to. I cannot recall any other weighing of metal other than running it over a

scale in order to keep a record of the amount of metal received from the blast furnaces.

X Q. 28. Did you use scrap steel before 1882 in the converters?

A. Yes.

X Q. 29. Why did you use it?

A. To make steel.

X Q. 30. You employed it, then, in connection with the cupola metal, did you?

A. At that time we used it entirely with the cupolas.

X Q. 31. Why did you put the scrap steel in with the cupola metal?

A. It was considered the best practice at the time to operate in this way. I might add that the methods of operating the Bessemer converter have changed very materially since 1882, and more than once. Reasons which seemed perfectly good then for any particular step, might seem very absurd today. For instance, at that time, to the best of my recollection, we required metal with
110 not less than 2½ per cent. of silicon. Today, we aim at about 1¼ per cent. of silicon.

X Q. 32. Can you not give me any reason why they put the steel scrap with the cupola metal into the converter in 1882 and before?

A. This is a matter I have not given any special attention to. In practice, when we make a change, we examine the results carefully from a financial standpoint, and if the change is satisfactory it is adopted. The previous practice becomes ancient history. But I can give a probable reason if that would be any use.

X Q. 33. What I was after is facts, and if you don't know them there is no use asking further. Do you know whether in using cupola metal in 1882 and before, they put different quantities of steel scrap into the converter in different charges; and if so, why they did so?

A. I understood your previous question to demand a reason for a fact. I gave you the fact. Now as to the other facts you ask for: The amount of scrap varied according to the judgment of a man called the "scrapper." His reason for varying the amount was to produce the best steel he could. The amount of scrap he put in was regulated from the appearance of the flame, and in his judgment such as to give the best results.

X Q. 34. What did the appearance of the flame indicate to the "scrapper"?

A. I never did any "scrapping" myself, but if you desire the information we can put one of the scrappers on the stand.

X Q. 35. Well, do you know enough to state that the appearance of the flame which guided the scrapper indicated the proportions of impurities or heat-producing elements, such as silicon or carbon, in the metal?

A. I presume it did.

X Q. 36. You have made some statements about the sale of the foreign patents for this Jones process to a syndicate known

111 as the Evans syndicate. Can you tell who were the members of that syndicate?

A. No.

X Q. 37. Don't you know the names of any of the parties who were members of the syndicate?

A. No.

X Q. 38. Taking the years 1882 to 1887, is it not the fact that the Edgar Thomson works were the largest producers of Bessemer steel in the United States during those years?

A. I think we were the largest producers.

X Q. 39. And you made the largest sales of Bessemer steel rails of any works of the country during those years?

A. I believe so.

X Q. 40. It is a fact, is it not, that during these years all the other manufacturers of Bessemer steel in the United States, except the Illinois Steel Co., were using what you term the "cupola process" in making their steel?

A. I believe your statement is correct.

Redirect examination by Mr. BAKEWELL:

R. D. Q. 41. In your direct examination you stated that in the use of the ladle in the cupola process, the ladle is never emptied and a fixed charge always secured. What was the purpose of never emptying the ladle, if you know?

A. The purpose of having more metal in the ladle than required for a charge, was to be sure to have always enough, and further when a cupola was tapped it is better to empty it, so that in this way surplus of metal has to be provided for.

GEORGE LAUDER.

112 *Testimony of A. M. Moreland.*

A. M. MORELAND, a witness produced by the complainant, being duly sworn, testifies as follows:

Direct examination:

Q. 1. State your name, age, residence and occupation.

A. A. M. Moreland; age, 31 years; residence, Pittsburg, Pa., occupation, assistant secretary and auditor of the Carnegie Steel Co., Limited.

Q. 2. Can you state what, if any, is the saving in the use of the Jones mixer process in a Bessemer plant?

A. Our records show a saving on an average of 65 cents per ton of ingots produced.

Q. 3. That is over the cupola process. Is that correct?

A. Yes, sir.

Q. 4. Please give an itemized statement of how this saving takes place?

A. By saving in loss of metal in melting in cupolas and blowing in converters,—25 cents per ton; labor at cupolas, 20 cents per ton:

expenses, repairs and supplies, 5 cents per ton; coke and limestone, 15 cents per ton. These figures make up the 65 cents.

Q. 5. This coke and limestone refer to the coke and limestone usually used in cupola furnaces?

A. Entirely.

Q. 6. Does this estimate that you have given include a saving at the blast furnace?

A. No, sir. Only applies to converting works.

Q. 7. From what source have you computed this estimate of saving?

A. By comparison of our actual cost at the Edgar Thomson steel works with those at the Duquesne steel works.

Q. 8. At the Edgar Thomson works they have been using a mixer. What process have they been using at the Duquesne works? I refer to the time your figures refer to.

113 A. We use the mixer process at Edgar Thomson, and the cupola process at the Duquesne steel works. We never used any other process at the Duquesne steel works.

Q. 9. How many blast furnaces have you at the Duquesne steel works?

A. None.

Q. 10. And you have therefore had to use the cupola process. Is that correct?

A. Yes, sir.

Cross-examination by Mr. KAY:

X Q. 11. How long have you been connected with the complainant company?

A. Thirteen years.

X Q. 12. In what capacity?

A. General clerk in the executive department for two or three years; since that time entirely in the accounting department.

X Q. 13. The figures given by you and taken from the records are based entirely on supposed savings as between the mixer process and the cupola process, and have nothing to do with what is known as the direct-metal process, in which the metal is carried from the blast furnaces to the converters and ladles without passing through the mixer, have they?

A. The figures represent the average actual difference in cost between the Edgar Thomson steel works and the Duquesne steel works, Edgar Thomson using the mixer process, Duquesne the cupola process. They do not include any savings in handling hot metal from the furnaces to the converting works.

X Q. 14. Well, they do not relate in any way to the use of the metal taken directly from the blast furnaces in ladles and introduced into the converters without passing through the mixers, do they?

A. They do not.

114 X Q. 15. Do you know whether the two plants, the Edgar Thomson works and the Duquesne works, are similar in all

other respects as to the production of Bessemer steel, except those due to the use of the cupola furnaces in one case, and the mixer in the other?

A. They are on an equal footing, with the exception that the Edgar Thomson has the advantage of having no cupola.

X Q. 16. Can you give any calculations from records of the cost of operating the mixers at the Edgar Thomson works? I mean the expense of passing the metal through the mixer.

A. The expense is trifling, so much so that we have not calculated it specially.

X Q. 17. Then you have no records of this expense to which you can refer?

A. I cannot recall the figures.

X Q. 18. Are you sure you ever calculated it?

A. I have done so in the past, but not recently.

X Q. 19. Do you know the size of the converters, either at the Edgar Thomson works or the Duquesne works?

A. Not accurately.

X Q. 20. Have you any records that will give it to you?

A. I can give an estimate if that will answer.

X Q. 21. I want the positive information if you can give it or get it.

(The witness is instructed that he need not give what is not in his power to give, and if he does not know the dimensions and has not in his possession or under his control records which will give the same, he is requested to say so.)

(The instruction of the witness is objected to and the course of complainant's counsel is protested against, as not permitting full and free cross-examination.)

115 A. I could procure it from the works. I have no record myself.

X Q. 22. Do you know how many converters they have at the Edgar Thomson works, and how many they have at the Duquesne works?

A. We have four at the Edgar Thomson works, but only operate two of them. We have two at the Duquesne steel works.

X Q. 23. Do you know enough about the operation to know that with the four converters at the Edgar Thomson they can run more continuously than with two at the Duquesne on account of stoppages for repairs, etc.?

A. We only use two vessels at the Edgar Thomson. The converters themselves run as continuously at one plant as the other.

X Q. 24. Can you state the greatest continuous period of rest for a converter at each plant in the regular operation?

(Objected to as not proper cross-examination, the expense and repairs of converters not having been alluded to in the examination-in-chief, only the expense and repairs of cupolas.)

(Mr. Kay calls the court's attention to the witness' answer 4, in which he refers in the first item to "melting in cupolas and blow-

ing in converters," and says that outside of this the question of expense is clearly governed by the matters referred to in the question.)

A. The reports that come to me do not show this.

X Q. 25. In giving your itemized statement in answer 4, you refer to melting in cupolas and blowing in converters. What loss is figured for melting in cupolas?

A. It would average not less than 3 per cent.

X Q. 26. I understand your testimony is given from records, and in so many cents per ton. Please state this loss in cents per ton.

A. We make our records from mixer to ingots.

116 X Q. 27. You have not answered my question. I am seeking to know on what you base your figures. Please give the figures for what I ask you in my last question?

A. My figures represent combined loss in cupola and converter vessels. We have no actual record to indicate the value of loss at cupola.

X Q. 28. Well, can you tell at all from records, or otherwise, how the blowing loss with metal drawn from the mixer compares with the blowing loss in using molten cupola metal, and if they are different, can you state why?

A. There is a difference of about one per cent. I cannot state from experience or observation why difference exists.

X Q. 29. Well, one per cent. of what, and in which direction?

A. One per cent. in favor of cupola practice in blowing at the vessel.

X Q. 30. One per cent. of what?

A. One per cent. of metals poured into the vessel.

X Q. 31. Is the loss of metal greater in the blowing operation, or the melting in cupolas? Have you any records as to this?

A. It is greater in the blowing operation. We have our practice reports.

X Q. 32. Well, how do these records show these losses to compare?

A. About 7½ per cent. on the mixer process, and 6½ on the cupola process.

X Q. 33. Please answer my last question relating to the comparative losses in the cupola and in the converter, respectively?

A. The loss in cupola is about 3 per cent. In converting by mixer process 7½ per cent.

X Q. 34. Please state the percentage of loss in melting the metal in cupola, if you have any records, or can give it otherwise?

117 A. It is about 3 per cent. on an average.

X Q. 35. Can you state the difference in loss in melting in cupola between chilled cast metal and sand-cast metal?

A. We have no separate records, not having used sand-cast metal singly.

X Q. 36. What is the percentage of loss in blowing cupola metal in the converter?

A. 6½ per cent.

X Q. 37. Can you state, from records, what percentage of metal made by blast furnace is turned out as steel ingots by the cupola process, by the direct process, and by the mixer process respectively?

(Objected to as not proper cross-examination, and as indefinite, the question not stating whether it refers to the output in the United States and in the world.)

(Mr. Kay presumes the witness has sense enough to know that the question asked relates to his knowledge of the operations of the complainant company.)

(The question is further objected to as there is no evidence in the case showing that the complainant company is now manufacturing by the direct process without the use of the mixer, or that the witness is acquainted in any way with such process, and in such case the question would be an enigma to him.)

A. The percentage would vary in accordance with the product of the blast furnaces. 60 per cent. of the pig-iron product at Edgar Thomson would be used at the converting works through the mixer, the balance would be shipped to outside parties, or disposed of in some manner elsewhere.

X Q. 38. Can you state from records what percentage of metal made by the blast furnace which is converted into Bessemer steel, is turned out as steel ingots by the cupola process, by the direct process, by the mixer process, respectively? I want the per-
118 centage of steel ingots that a ton of blast-furnace metal would make by any one of these three processes, which will give the percentage of waste in the normal operation of the three processes?

A. I only know of the mixer and cupola processes particularly. At the Edgar Thomson steel works with the mixer process we would produce about 92 per cent. of ingots from the mixture of metal; at the Duquesne steel works, with the cupola process, about 90 per cent. of ingots. This allows at Edgar Thomson 7½ per cent. for loss in blowing, and one-half of one per cent. for scrap. This scrap is produced in blowing in the vessels and in pouring in the pits. At the Duquesne steel works the loss in cupola is about 3 per cent, at converter vessel 6½ per cent., and the scrap production is about one-half of one per cent. This makes with 90 per cent. of ingots produced 100 per cent. for the cupola process.

X Q. 39. How much scrap is there between the blast furnaces and the mixer?

A. I do not keep a record of the tonnage produced between the furnaces and the mixer.

X Q. 40. Is there any scrap made between these points?

A. There is an accumulation in the ladles which is termed scrap when it is removed therefrom.

X Q. 41. How much scrap is formed in the mixer and in the ladle conducting the metal from the mixer to the converter? I mean, of course, what per cent.

A. It would average from 2½ to 3 per cent.

X Q. 42. Can you state the expense per ton of repairing and keep-

ing in order the ladles which carry the metal from the blast furnaces to the mixer?

A. It is very small, something like one per cent. per ton, or less.

X Q. 43. Have you any records to which you can refer and fix this accurately?

119 A. No, none, except my recollection of figuring it and separating it from other work. We do not keep the cost of this as a separate item on our books.

X Q. 44. Is it not the fact that you keep a separate gang of men employed specially for repairing and cleaning these ladles?

A. Yes, but in comparison with the large tonnage produced, the cost is exceedingly small.

X Q. 45. When Mr. George Lauder was on the stand, I asked him certain questions as to which he said he would refer to the records, and finally said he would prefer to put a man on the stand who would give the information desired from his own knowledge. Can you from the records of the company give the information asked for, which is as follows, to wit:

1. The capacity of the ladle carrying the metal between the blast furnaces and the converters in employing the direct process.

2. The converter charge employed between 1882 and 1887.

3. The capacity of the cupola ladle which received the metal from the cupolas and charged it into the converters as employed at the Edgar Thomson works, prior to 1887.

The last point refers to the ladle used prior to 1882, from 1882 to 1887, and for some time after the later date. These questions all refer to the Edgar Thomson works.

(Objected to as not proper cross-examination.)

(Counsel for complainant states that he has no objection to furnishing the information and will have a written statement as to these facts prepared and furnished to counsel for respondent. He does not see how this matter relates to the cross-examination of this witness in any way.)

(Mr. Kay states that will be satisfactory if the statement is furnished to him, and he presumes he will not have any cross-

120 examination in regard to it, and if this is the case he will stipulate that it be entered in the record to complete Mr. Lauder's examination. He asks the questions of this witness because he had understood that Mr. Lauder would furnish a witness who would give this information and had been informed that this would be the last witness called before complainant closed its case.)

(Counsel for complainant states that he will furnish a statement, but that he does not see how there can be any cross-examination on the stand, Mr. Lauder's offer not having been accepted at the time it was made.)

(Mr. Kay states that he understood that the witness would have this information, taken from the records of the company, and expected Mr. Bakewell to ask the witness about them.)

A. I cannot give this information off-hand, not having investigated.

Redirect examination by Mr. BAKEWELL:

R. D. Q. 46. From your testimony, I understand that the loss of cupola metal in the cupola is 3 per cent., and the loss of such metal in the converter is 6½ per cent., making a total loss by the cupola process of 9½ per cent. Is this correct?

A. Yes, sir.

R. D. Q. 47. I understand from your testimony, that the loss of mixer metal in the converter is 7½ per cent., which would give a saving by the mixer method of 2 per cent. Is that correct?

A. 2 per cent. is the average saving in loss, as stated.

R. D. Q. 48. When metal becomes scrap, as spoken of by you in X Q. 41, is this counted as so much less, or not?

A. No. It has a value.

R. D. Q. 49. In the answer to Q. 4, you refer to expenses, repairs and supplies, 5 cents per ton. Does this refer to expenses, repairs and supplies, with the cupola furnace, to the converter, or to both?

121 A. It represents the excess expense at cupolas as against a converting works without cupolas.

Recross-examination by Mr. KAY:

R. X Q. 50. What is done with the scrap referred to in redirect question 48?

A. It is melted in the blast furnaces as fast as it is made.

A. M. MORELAND.

Mr. Kay, defendant's counsel, states that as there has been a verbal statement of the complainant's intention to move the court for an order closing the defendant's case, as soon as complainant closes its opening testimony, he would request that if there is any intention to make such motion before his, Mr. Kay's, return from Europe early in October, this motion be made so that it can be heard before the court not later than next Monday, June 1st.

Notice is hereby given that a motion for respondent to close the taking of its testimony at a fixed time will be made before the court on Monday morning at 10 o'clock.

Mr. Kay now repeats the inquiry made of Mr. Bakewell whether it is the intention of complainant to insist upon infringement of the two claims of the patent in suit, and if not, on which of said claims he proposes to stand at the hearing; and requests that this inquiry be answered before the closing of complainant's opening testimony.

As counsel for complainant fails to see any reason at present why he should not insist upon infringement of both claims, he does not at present desire to limit himself to either of said claims in this suit. Counsel for respondent may therefore assume that both claims are relied upon.

122 *Testimony of David Evans.*

Testimony taken on the part of complainant, on agreement of counsel, at the Buckingham hotel, this fourth day of November, 1895.

Present: Mr. J. K. Bakewell, on part of complainant; Mr. P. T. Dodge, on part of respondent.

DAVID EVANS, a witness, being called and sworn, deposes as follows:

Q. 1. State your name, age, residence and occupation.

A. David Evans, general manager Bolckow Vaughan Co., Ltd., Middlesborough on Tees, England, age 54.

Q. 2. What business is Bolckow Vaughan Co., Ltd., in?

A. Coal, iron, stone, pig iron and steel manufacturing—I mean producers of coal, iron and steel, and pig iron and steel manufacturers.

Q. 3. How large a plant has this company?

Counsel for defendant here enters objection to any and all testimony respecting matters and things outside of the limits of the United States, as irrelevant, incompetent and immaterial.

A. We have 26 blast furnaces, 20 in blast.

Q. 4. What practical experience have you had in the manufacture of pig iron and steel?

A. I was brought up at Aberdare, South Wales, and served through the various departments. In 1866 I succeeded my father as manager of those works. In 1870 I left for the Rhymney iron works, South Wales, where they have nine blast furnaces. I managed there the furnaces and forges and mills. In 1875 I was appointed technical manager of the Ebbw Vale Iron and Steel Co.,
where we had fourteen blast furnaces, until 1878, when I re-
123 turned to Rhymney as general manager. I remained there in that position until 1885, when I was appointed general manager of the Barrow Hematite Iron and Steel Co., where we had fourteen blast furnaces. I remained there until September, 1891, when I was appointed general manager of Bolckow Vaughan Co., which position I still hold.

Q. 5. Have you ever visited other iron and steel works in England?

Counsel for defendant desires it understood that the objection above noted continues until further notice.

A. Yes, I have visited the principal iron and steel works in England and Wales and Scotland, also the principal continental works.

Q. 6. Are you familiar with the general literature with regard to the art of the manufacture of iron and steel?

A. Yes, I read the principal technical papers and books that

are published in the United States, the United Kingdom and the Continent.

Q. 7. Did you ever meet Capt. W. R. Jones, of the Edgar Thomson Steel Works of Pittsburg?

A. Yes, in September, 1888, when he came over on a visit to the United Kingdom, during the Iron and Steel Institute meeting in Scotland. He also visited me at the Barrow works.

Q. 8. Did you have any conversation with Capt. Jones in regard to producing steel by direct process? If so, how did this conversation arise, and what was its substance?

A. We had great difficulty at Barrow in consequence of the varient qualities of the ores used in the blast furnaces. The pig iron produced varied so much in silicon and other metalloids that we had great difficulty in using direct metal for our steel works. He explained to me that he had just invented a mixer that would get over this difficulty, by having this mixer so large it would enable us to draw various casts from different furnaces, and that this
124 would give us uniform quality, that would enable the blower or steel-maker to work with greater precision and give us more satisfactory results. I put this matter before my directors, and they decided that my son should visit the States and return with Capt. Jones. He remained some months at the Edgar Thomson works and reported so favorably upon the good results obtained there, that my directors decided to erect a mixer at Barrow, and this gave or fulfilled every promise that Capt. Jones mentioned, and produced for us very much more economical results.

Q. 9. What was the purpose of your son accompanying Capt. Jones to the Edgar Thomson works at Pittsburg?

A. The object was to qualify the statement that Capt. Jones made in reference to the invention that he had adopted at the Edgar Thomson and at that time it had only been working for a short time; therefore he wanted my son to go over and remain at the Edgar Thomson works until he was satisfied that the mixer would be advisable to be adopted at our Barrow works.

Q. 10. You have spoken of the direct process. Please state what it is, and what experience you have had in regard to it.

A. In 1876 when I was manager at Ebbw-Vale I was one of the first to use direct metal from the blast furnaces to the converters. We experienced there the same difficulty as explained before, that through the varient quality of ores used in the blast furnaces, it was not possible to obtain uniform results, the silicon sometimes being so high that it may take about two tons of scrap in the charge, while other casts from the furnaces would not take any scrap. Consequently, there will be great variation in the weight of steel produced from various charges of the converter, and consequently there will be a want of uniformity in the carbon and manganese.

Q. 11. What would be the result of this want of uniformity?

125 A. The result, as stated before, would be hard or soft rails, and consequently we should also make more defective rails or seconds.

Q. 12 Please describe what the direct process is.

A. The direct process is taking pig iron in the molten state, direct from the blast furnace where it is produced from the ore, in a ladle direct to the converters, where it is converted into steel.

Q. 13. What is the cupola process?

A. The iron is run from the blast furnace into molds, forming pigs. This, after being cooled, is loaded into wagons and taken to the cupolas to be remelted by using coke and blast, and melted and run into ladles, and then conveyed to the converter.

Q. 14. Then I understand that the use of the direct process saves the remelting of the metal in the cupola furnace. Is this correct?

A. Yes. And the cupola process is a very costly one in labor, fuel and waste, in remelting.

Q. 15. Why was the cupola process employed prior to Capt. Jones' invention?

(Objected to if it is intended by this question to convey the idea that the cupola or the direct process disappeared from the art after the alleged date of the Jones invention.)

A. The cupola process was used in the early days of steel manufacture and is still used occasionally in remelting pig iron when there is not sufficient molten iron coming from the blast furnaces. But since Capt. Jones' invention of the mixer, most firms who have blast furnaces in England and on the continent have adopted the mixer and so save the expense of remelting.

Q. 16. What are the advantages that the cupola process has over the direct process, where the mixer is not employed—that is, why did they not, prior to the introduction of the mixer, use the direct process entirely?

126 A. Prior to the invention of Capt. Jones several firms used the direct process, but the results were not very satisfactory, as explained before, through want of uniformity. The results obtained gave a large number of defectives. But since the adoption of the mixer at the various works I have been engaged, we have reduced the defective or second-class rails fully one-half, and also saved the remelting.

Q. 17. Please state how, by the use of the cupola process, which you state is an additional and expensive process, the number of defective rails is lessened. What is the effect of the cupola process—how does it lessen the number of defectives?

A. When using the cupola process, you have an opportunity of grading the iron by analyzing the various casts and classifying it, and mixing these various grades in the cupola for remelting, so as to get a general average. But even with this, in remelting the iron takes up a certain amount of sulphur which is very injurious to the product obtained.

Q. 18. Please describe fully Capt. Jones' mixer process as he described it to you, and as you have employed it.

A. Capt. Jones' mixer is a large vessel mounted on wheels or trun-ions to enable it to be tilted, so that the various charges from the blast furnace should be commingled or thoroughly mixed in pouring to the ladle for the converters. Where we have a large

number of blast furnaces we draw various ladles from several furnaces. This is taken to the mixer and poured in, the object being to have uniform quality from the various furnaces, and this is obtained satisfactorily by the addition of the tilting of the metal into the ladles. The mixer on Sunday night will be heated up by coke or petroleum a few hours before the steel works commence work. We then take ladles of molten iron from the different furnaces and fill the mixer up to its full capacity. This process goes on during the week until Saturday, when the steel works
127 close, constantly taking from the furnaces the molten iron to the mixer as fast as the molten iron is withdrawn from it to the converters. That is, we keep the mixer always full, so it gives ample opportunity for the charges of the various furnaces to be thoroughly mixed. This is aided by the tilting process each time the mixer is tipped to the ladles for the converters. When the steel works close down we close up the apertures of the mixer perfectly air-tight until it is required again on Sunday night.

Q. 19. Do the steel works close up every night?

A. No, our practice in England is to close down on Saturday, middle of the day, and start again on Monday morning, when we work continuously until the following Saturday.

(Counsel for defendant again urges his objection, heretofore made and still running, to this entire line of examination for the reason that the practice which may have prevailed in works outside of the United States, is incompetent, immaterial and inadmissible, under the statute.)

Q. 20. Then I understand you that you commence filling up the mixer on Sunday night, and strive to keep it full or nearly full until Saturday, the metal being drawn off as required for the converter, and fresh metal being added from the blast furnaces?

(Objected to, the witness not having used the words "nearly full.")

A. Yes, that is so.

Q. 21. Instead of using the mixer, why could you not successfully determine the quality of the output of the different furnaces and then, having once determined the quality of the metal that was coming from that furnace during the week, draw from the ladle from a furnace giving a high grade of silicon, and a furnace giving a low grade of silicon, and thereby obtain a general average without the use of the mixer?

128 A. As stated before, the quality of the iron varies considerably from each cast from the furnace, and this was the difficulty we found when using the direct process in a small ladle for the converter. We found it difficult to know the exact grade of iron accurately enough from each cast, as it was put in the ladle. It was also not practical to tap from various furnaces producing large quantities of iron, such small quantities of iron to give us a thorough mixture. Hence the reason of taking the iron direct from

one furnace, which iron varied greatly in metalloids and gave us unsatisfactory results in the steel department.

Q. 22. What is your opinion as to practical value of the Jones mixer process?

(Objected to, it not having been stated by or to the witness what the limits of or the exact nature of the so-called Jones process is.)

A. The Jones process has been introduced by us in England at Barrow, and also at Bolckow Vaughan Co. I have a thorough knowledge of the practical working of the Jones mixer, as used at Barrow, and as we are now using at Bolckow Vaughan & Co., and can testify to the great advantages we have derived from its adoption, by giving us a constant supply of metal to our Bessemer department, and this of a uniform quality which was not derived before. Therefore, we are deriving great economy from its use.

Q. 23. In your long experience as manager of plants for the manufacture of steel, did you ever know or hear of any process other than the cupola by which the practical results have been or could have been secured, which you have stated as resulting from the use of the Jones mixer?

(Objected to for reasons above given, and also for that the negative statements of the witness are incompetent, as evidence in support of any facts which may be attempted to be proved.)

A. I have not.

129 Q. 24. Supposing that instead of charging the mixer directly from the blast furnace alone, some pig metal were melted in the cupola and then charged into the converter with a charge from the mixer, so that half of the metal charged to the converter would be from the mixer and half direct from the cupola, would this, in your opinion, be a material variation from the Jones mixer process?

A. That would depend upon how the iron would be mixed in the cupola. As stated before, that iron would take up sulphur from the coke in being remelted, but with a half from the mixer I should say the result would be the same, with the exception of that slight variation in the mixing of the iron and the sulphur taken up by the coke. I do not see the object when you have a mixer, of remelting, provided you have sufficient supply of molten iron from the blast furnaces. It may be, however, that the cupola is employed where the firms using the mixer have not sufficient blast furnaces to keep their Bessemer plant fully going. They therefore remelt iron they may have when the steel works are not working during week ends or during Sunday.

Q. 25. Are you acquainted with the patent of Wm. R. Jones, on which this suit is brought?

A. Yes; I have read the patent.

Q. 26. I do not ask you as a patent expert, but as a practical expert—considering the Jones patent as a technical description of the process. State whether or not, in your opinion, the process de-

scribed in the Jones patent is the same as that practiced by you at the works in England over which you are general manager.

(The objection running on the part of defendant's counsel is discontinued as to future questions.)

A. The process adopted by us in England is exactly the same as Capt. Jones' invention. At Barrow the mixer was made from drawings which Capt. Jones supplied, and the one in use at Bolekow varies a little in shape, but gives us the same practical results.

130 Q. 27. Having read the Jones patent, do you consider the process described therein the same as the process you have described as used by you in England? If not, state in what particular.

A. The process is exactly the same as Capt. Jones' invention and as he used in the Edgar Thomson works.

Q. 28. Is it the same process that is described in the patent which you say you have read?

A. Yes; exactly the same.

(Counsel for complainant here states that the witness resides in England; that he came to this country on other business than giving testimony in this suit, and that owing to his professional duties in England, he has to sail for there on Saturday of this week, and by reason of his duties, it may be impossible for him to return to this country at the time of taking testimony in rebuttal on the part of complainant. The testimony in rebuttal in this case having been unavoidably delayed for various causes, counsel for complainant therefore takes the following testimony of the witness, *de bene esse*. To which counsel for defendant consents, reserving all rights of objection which he would have had, had this testimony been taken in regular order.)

Q. 29. Have you ever heard of a patent granted to Wm. Deighton, in England, in the year 1872 and numbered 3872?

A. Yes, and I have carefully read it.

Q. 30. Do you know whether the process therein described has ever been put into practical use?

(Objected to as being incompetent for the witness to testify except as to his personal want of knowledge.)

A. I am not aware of it, and I don't believe it has ever been used.

Q. 31. Why do you think it has never been used?

131 (The same objection is urged, and the further objection that it does not appear that witness is familiar with the practice generally in the United States, which is alone admissible in this cause.)

A. Because I do not see that it would be a success. It would not be a success, nor useful, nor economical.

Q. 32. Would you be willing to introduce it into your works?

(Objected to, the witness' opinion on this point having no value, direct or indirect, upon the question of infringement or the validity of the Jones patent in suit.)

A. Certainly not.

Q. 33. In your judgment could the practical results of the Jones mixer process be obtained by the use of the Deighton process, as described in his patent?

A. No; it cannot, because the mode described in the Deighton patent refers to a fixed receiver to take the molten iron from one or two furnaces; this receiver being so small that it could not give better results than that obtained by the direct process, by tapping the charge into a ladle—a small ladle on a carriage. This would not give a proper mixture, and consequently would not be useful. The receiver also is open at the top and would cool the metal, and as described in the patent, they would only serve one converter.

Q. 34. Is there any provision in the Deighton patent for the agitation of the metal, such as would be produced by the tilting of the Jones mixer?

A. As I have read it, there is none; and that of itself is a very great objection, because you cannot get uniformity in the molten metal without tilting.

Q. 35. Is there any mention in the Deighton patent of a continuous process such as is described in the Jones patent?

132 A. No; there is not, and I do not see how it is possible to adopt it where there is a large number of blast furnaces.

Q. 36. Is there anything in the Deighton patent that would suggest to a man skilled in the art, the use of the Jones process as you have described it?

A. No; there is not.

Q. 37. Have you any interest in the present suit?

A. None.

Cross-examination by PHILIP T. DODGE, of counsel for defendant, without waiver of objection:

(Counsel for defendant here asks counsel for complainant to state whether, at the hearing of this cause, it is his intention to urge infringement of both claims of the patent in suit, if not on which claims he proposes to stand?)

(Counsel for complainant replies that he is only one of the counsel for complainant, but that so far as he is at present advised he believes that infringement is charged as to both of the claims of the Jones patent.)

X Q. 37½. Except as to the mixing of the different charges from the blast furnace before going into the converter, in what respect, if any, does the making of steel under the Jones process differ from the ordinary Bessemer practice?

A. As stated before, when direct metal was used on the blast furnaces, the process was costly, and to save the remelting it was necessary to mix the metal in large quantities to obtain economical

results. The same process, only it enabled us to use ores and pig iron which we could not very well use before. There is no change in the process besides that.

X Q. 38. You have repeatedly referred to the Jones process. Now that the court may understand, will you state in your own words what you understand the Jones process to be?

133 A. The Jones process is the adoption of a large receiver or mixer to take various ladles full of iron from a number of blast furnaces; the object being the equalization of the pig iron, and by dipping into this receiver and tilting the metal into a ladle for the use of the Bessemer process, without this process called the Jones mixer, the direct process was not a success.

X Q. 39. I will read you from the Jones patent as follows: "My invention is not limited to its use in connection with converters, since similar advantages may be obtained by casting from the mixing vessel into pigs, for use in converters, puddling furnaces or for any other uses to which pig iron may be put in the art." In view of this statement in the patent, do you still think that the invention is limited to the use of the mixing vessel in a Bessemer process? I ask you, not as a patent expert, but as a skilled worker of steel and other metals.

(Objected to as the question does not appear to have any force excepting as to the construction of complainant's patent, and the witness has not been called as an expert in regard to such construction.)

A. I should say that the metal after being in the mixer would be improved for puddling or the Siemens process, but I cannot see the use of putting the iron into the mixer and running it into the pigs for the use of the Bessemer process, as this can be done equally as well by using the metal direct in the molten state and saving the expense of remelting.

X Q. 40. In your practice under the Jones process, you employ metal from the same blast furnaces and from the same one as before the introduction of the Jones process?

A. Practically the same. There may be some variation in the ores every month as we go on. We do not always buy the same ore.

134 X Q. 41. And since the introduction of the mixer you have treated the metal going into the converters in the same manner that you previously treated metal put into them to make steel?

A. Yes, with the exception that we are able to use more metal from our blast furnaces direct. Before the adoption of the mixer, the pig iron varied so much in quality that we could not use it all, and this iron had to be remelted also as a lower-grade iron.

(Complainant's counsel states that although he believes that both claims are relied on, he does not desire to be bound by this statement, but he will, at the earliest opportunity, consult with the other counsel in the case and inform counsel for respondent as to this matter.)

X Q. 42. But the metal which is put into your converters is treated in the same manner as the metal which you put into them before you used the mixer, is it?

A. Yes.

X Q. 43. Am I not correct in saying that the principal object in using a mixing vessel is simply to mix or combine mechanically different charges of metal which differ somewhat in composition, so that you may obtain a uniform or average product as the result of the mixing?

A. We get rid of a little silicon and also sulphur, and the principal object of mixing the various casts is to get an uniform chemical composition of the various metalloids from the mixing, which results from the mechanical mixture of the constituents.

X Q. 44. Do you think that you get rid of any sulphur when using metals that contain no manganese?

A. We do, slightly.

X Q. 45. Tell us why, please, or how.

A. When the metal is in the mixer, you will find a certain amount of sulphur coming through, because it is of lighter specific gravity, when the metal is stationary it comes to the top.

135 X Q. 46. How large must the mixer be, in your opinion, to come within the Jones process as you understand it?

A. The Jones mixer, the smallest is ninety tons capacity. We use 150 tons.

X Q. 47. Do you think if the mixer was less than 90 tons capacity it would be outside of the Jones invention, as you understand it?

A. No, I do not think so, because he does not confine himself to a minimum of 90 tons. He describes a vessel or receiver large enough to receive various casts from the blast furnaces, and by commingling this metal in the receiver and tilting, you get uniformity which, in my opinion, you cannot have in a small fixed vessel or ladle.

X Q. 48. I suppose the size of the mixer is a matter which rests within the skill or judgment of the engineer who designs the works?

A. I suppose so, but those I know of are made as stated from 90 to 150 tons, and I should say the larger the better.

X Q. 49. But change in the size of the mixer, making it larger or smaller, would not vary the principle or the process of making, would it?

A. No, but it would vary the results, if it were very small.

X Q. 50. If an engineer were told to make the receiver or vessel for mixing molten metal from two or more furnaces to get a more uniform quality of metal, his skill and judgment as an engineer would enable him to determine the size of that vessel, would it not?

A. I suppose so, but until Capt. Jones invented this mixer, no one in our country or any other that I know of ever attempted, in making receivers of such a size, that would give proper mixing of the metal from the blast furnaces. Before then it was only done in small quantities in the ladle, which was not practical or successful.

136 (All after the first three words is objected to as irresponsive and voluntary.)

X Q. 51. The mixing of the charges in the Jones mixer are due, in part, I suppose, to the fact that whenever the molten metal is poured into the vessel, it will necessarily agitate and mix the mass to some extent?

A. To a very small extent, and will not, in my opinion, without tilting, mix the metal properly.

X Q. 52. The Jones mixer which you use is a long vessel arranged to tip or pitch endwise over a fulcrum beneath its middle, is it not?

A. At Barrow, yes. At Bolckow it tips on the end.

X Q. 53. But in each case you use an elongated vessel and tip it in the direction of its length, so that the metal is pitched endwise in the vessel, and thereby agitated and more thoroughly mixed. Is that so?

A. Yes.

X Q. 54. And if I understand your previous testimony correctly, this pitching or surging of the metal endwise in the vessel, is necessary to secure the thorough mixing of the different charges?

(Objected to as the witness did not allude to endwise surging of the metal as distinctive from sideways.)

A. Whether you move it endwise or sidewise, it is necessary to have a tilting motion.

X Q. 55. But the motion must be such that the entire body of the metal shifts or pitches in the vessel to cause the mixing of the different charges?

A. Yes, it is better to have that motion, whichever way you may apply it, whether by tilting sidewise or endwise.

X Q. 56. Are you aware that long prior to the Jones patent tilting vessels of large size covered and mounted on trunnions, were known in the art and described in printed publications?

(Objected to unless some connection is shown between the question and the Jones process, considered as a whole.)

137 A. I am not aware of that, and if it had been in use in our country I should have certainly known of it.

X Q. 57. To carry out the Jones process do you think that a circular vessel turning around its horizontal center or axis would give the agitation necessary to the mixing of the metal by its rotation?

A. How is the metal poured in?

X Q. 58. We will assume that the metal is poured into one side of it.

A. I don't think it would do it so well.

X Q. 59. Am I correct in understanding it to be your view that for the mixing of the charges contemplated by the Jones process, there must be in addition to the agitation which results from the pouring in of such charges, a further agitation due to the shape and motion of the vessel?

(Objected to in so far as the question may apply to any construction which may be put upon the Jones patent.)

A. I think it will be better to have the further motion. I think

the metal will be better mixed when it is tilted endwise, and I think that is better than when it is tilted sidewise. They do get the mixing when it is tilted sidewise, but not so effectually as in the other way.

X Q. 60. What shape of vessel have you seen tilted sidewise?

A. I understand there is one at Chicago. I saw it at a distance, but did not examine it closely.

X Q. 61. Then you could not say of your own knowledge as to the construction and operation of any mixer which tips sidewise?

A. No; I cannot.

X Q. 62. When and where did you first recommend the adoption of the process with a mixing vessel?

A. The report I got from my son was in November, 1888, and we adopted the mixer at Barrow in the spring of 1889.

138 X Q. 63. Is it not a fact that the mixing of different charges from the blast furnaces to secure a uniform or average quality of the metal would be advantageous in securing a uniform quality of metal for puddling furnaces or for foundry purposes?

A. I should think it would, although my experience of puddling has been lost sight of for over 20 years, and all the works I have been connected with since 1876 have practically abandoned puddling.

X Q. 64. It is a fact, is it not, that the mixing of molten metal from different furnaces, or of different charges from the same furnace, in a receiving vessel, would give a uniform or practically uniform product for whatever purpose it might be afterward used?

A. It depends on what shape the vessel would be—the vessel or receiver. I am not aware of any being in use for the purpose of the manufacture of steel; as for mixing for foundry purposes I have no experience in it, and therefore cannot give an opinion.

X Q. 65. In your opinion would it be possible to carry out the Jones process with a fixed mixing vessel?

A. I don't think so. You could not mix a metal so thoroughly without a motion.

X Q. 66. What kind of a vessel do you understand it is necessary to use to carry out the Jones process as described in his patent you have referred to?

(Objected to in so far as the question is intended to place any construction on the patent.)

A. We have practically followed Jones' method in construction, with the exception of making it cylindrical, with the tilting motion practically the same as in the Jones patent.

X Q. 67. The metal which you use in the converters for making steel is simply crude cast iron, as it comes from the ore, is it not?

139 A. Yes.

X Q. 68. The metal you use in your converters is of the same character or composition as the pig iron of commerce, commonly used in foundries?

A. No; it is different. The manufacture of Bessemer iron is dif-

ferent from that which is used for foundry purposes. The pig iron we manufacture for the manufacture of steel is made from Spanish ore. We also make special pig iron for the manufacture of steel for basic process. We also manufacture large quantities of foundry iron made exclusively from Cleveland iron stone. The basic iron is specially made for the basic process from Cleveland and other materials.

X Q. 69. You make from the same furnaces, and from the same ores, pig iron, some of which is used in the manufacture of steel and some of which is used for foundry purposes?

A. We make special iron for our Bessemer steel from Spanish ore. We make special basic iron in separate blast furnaces, also foundry iron which is all run into pigs and sold direct from the pig beds to foundries.

X Q. 70. These are all pig irons, which come from the blast furnaces and which differ in the percentage of their different elements according to the ores from which they are made; is that right?

A. That is so; and used for various manufactures.

X Q. 71. Referring to the Jones patent, what do you understand to be meant by the expression "charging ladle" in lines 84 and 85 of the first page?

(Objected to in so far as it relates to the construction of the Jones patent.)

A. My idea is that the molten iron is conveyed by it from the various furnaces to the mixer.

X Q. 72. What is a charging ladle, so called, in the ordinary Bessemer process where the Jones mixer is not used?

140 A. A charging ladle is a ladle that takes the molten iron from the blast furnace to the mixer, or where the mixer is not employed it is conveyed to the converter or from the cupola to the converter.

X Q. 73. Is it not a fact that many steel works are running in America and Europe with the direct process and without the Jones mixer?

A. I do not know of any works in England who use the direct method without largely remelting the pig iron in the cupolas; as stated before, in my experience and the experience of other manufacturers who have adopted the mixer, it is not possible to work so economically by this method as without the mixer.

X Q. 74. Do you not, in your own practice, use cupola metal in addition to the metal directly from the blast furnaces?

A. We do sometimes when we have not sufficient molten iron to keep our Bessemer plant fully going. We also remelt the basic iron made during the week and while the steel works are standing idle, and take that afterwards and put it through the mixer. Other works in our district work on the same lines. We find it an advantage to mix the iron from the cupola with the iron taken direct from the blast furnaces to the mixer. The Northeastern Steel Co. does exactly the same as we do.

X Q. 75. To what other works do you refer?

A. The Northeastern Steel Co.

X Q. 76. The metal which you take from the cupola is a remelted and refined iron, or has greater uniformity than the crude metal taken from the blast furnace, has it not?

A. Not necessarily. It depends upon what iron you put into the cupola. It gives us an opportunity to remelt either a high or low grade iron and put that through the mixer for uniformity and economical working. That is, we are able to so regulate the
141 charges for the converters by mixing these different grades in the cupola and putting it through the mixer and so get rid of some low-grade iron which we should have to get rid of at a lower price.

X Q. 77. Will you state in your own way, what you understand to be the differences between the Deighton and Jones processes?

A. I do not see any comparison anyway. The Deighton process as I understand it, fixes a—places a fixed receiver close to the converter and two blast furnaces as ranged for tapping the molten iron into it; but this receiver being so small I cannot see how we can get a thorough mixture of the metal; neither do I know of this having been done. If this had been so, I cannot understand why since 1873 until 1888, when we were all trying in various ways to get a uniform quality of molten iron for the use of the converters, this had not been adopted, and until Capt. Jones came forward with his invention, no firm in our country had been able to work as economical from the direct process as they have been since Jones' invention.

The attention of the court is directed to the manifest animus of this witness and to the constant injection of arguments and inferences into the record instead of answers confined to the matter in question.

The witness is asked in future answers to confine himself to specific answers to the matters asked of him.

(Counsel for complainant requests the examiner to take down all remarks of counsel for respondent to the witness, of whatever character they may be.)

X Q. 78. Does the distance of the receiver from the converter form any essential part of the Jones process as you understand it?

A. Yes, because it is not possible to fix the mixer close to the Bessemer and run the molten iron into the converter without
142 it being conveyed in ladles, therefore it is a question of space and convenience as to where they should be placed, in various works where it may be adopted.

X Q. 79. How far do you understand that the mixer must be from the converters to meet the requirement of the Jones process?

A. That depends on the works adopting the mixer. Where the plant is in existence before, we have it placed at a convenient position between the furnaces and the converter. As the metal has to be conveyed in a ladle to the mixer, and from it to the converter, the question of distance does not affect the question.

X Q. 80. Am I correct, then, in understanding that the mixer

may be placed in one position or another, as convenience and the arrangement of the works may dictate?

A. That may be so.

X Q. 81. The mixer as used by you is not adapted for removal from one place to another, is it?

A. Ours is fixed between the blast furnaces and the Bessemer converters—the most convenient position we have.

X Q. 82. Am I to understand from your criticism of the Deighton patent that the Jones process could not be worked with a fixed receiver?

A. That is my opinion, and get uniformity in the molten metal.

X Q. 83. Have you calculated the capacity of the receiver or vessel *m* in the Deighton patent in relation to the capacity of the converters shown in the patent?

A. I have not, but judging from looking at the drawings, it is of such a size that will permit sufficient metal from several blast furnaces to run into it, to obtain a uniform mixture.

X Q. 84. You have referred in your testimony to the Deighton receiver or mixing vessel receiving metal from two blast furnaces. Is it not true that the patentee describes it "as a receiver or
143 receptacle *m* for mixing molten metal from two or more smelting furnaces, to get a more uniform quality"?

A. Yes, but I cannot see how he can bring the metal to the receiver from two or more smelting furnaces.

X Q. 85. Is it not true that the Deighton patent refers to four furnaces as delivering to the receiving vessel or mixer *m*, and that the drawing shows four conductors for this purpose? I am simply asking you as to whether or not the patent contains these things, not whether it will work or not.

A. Yes, looking again at the drawing, it does show four gates or channels, but I still consider the receiver too small to hold sufficient metal to give uniform quality from the blast furnaces. There is also the objection that the distance from the furnaces to the receiver is so great that there will be an enormous loss of metal continually remaining in these gates or channels. I consider the receiver also being a fixed one objectionable, as it is difficult sometimes to hold the metal back by tapping from it. This is avoided in the Jones mixer by tilting it—by tilting it back and forth in tapping to the ladle.

(All after the word "channels" is objected to, as voluntary and not in answer to the question asked.)

X Q. 86. How much larger do you think that the vessel *m* in the Deighton patent would have to be in order to give any advantage whatever in mixing the metals or improving the uniformity over the single charges from the blast furnace?

A. I do not believe in the Deighton receiver, and would never adopt it; therefore I cannot express an opinion on the receiver as to what size it would be necessary to make it for the mixing of metal.

X Q. 87. Do you wish the court to understand you as saying that

if you should deliver the metal from two or more blast fur-
144 naces into a receiver of the relative size shown in the Deighton patent, it would not improve the quality or uniformity of the metal?

A. It will to some extent, but the cost of the runner and waste and the cooling of the receiver by being open at the top, is not a good kind to adopt, and from my knowledge it has not been adopted, and if it was it would not give satisfactory results.

X Q. 88. Did you never hear or know of a tilting vessel adapted to hold molten metal and covered at the top to prevent loss of heat, until you heard of the Jones construction?

A. No, I did not, that is, of any size as to make the receiver—that would make the receiver of commercial value, by which a large quantity from various blast furnaces could be held.

X Q. 89. Having read the Deighton patent, you do not doubt, do you, that the patentee saw the difficulty and want of uniformity which resulted in taking the metal directly from the blast furnaces to the converter?

A. There is no doubt that he saw the difficulty and tried to get over it, but I never heard that he succeeded in doing so, as it was never adopted to my knowledge according to the plan shown.

(All after the words "over it" is objected to as irresponsive and voluntary.)

X Q. 90. The patent of Deighton gives you to understand, does it not, that he saw that the variation between different blast-furnace charges was to be overcome by mixing those charges together to get an average result or product?

A. No doubt he saw the difficulty and the want of uniformity of the molten iron from the blast furnaces, but I do not consider his patent a practical one nor an effectual one.

(The entire answer is objected to as irresponsive and the question is repeated.)

145 Mr. DODGE: Re-read the question, as I don't believe he could have understood my meaning.

Question repeated.

A. Yes; he says so in his patent. The patent says so, but I do not believe in the way he was going to carry out the work.

(All from and including the word "but" is objected to as not in answer to the question, the witness not having been asked as to his opinion.

Counsel for complainant desires to state in the record that the witness is entitled to explain or qualify any answer given by him, especially when it calls for his opinion, and he makes this statement for the instruction of the witness; but he asks the witness to carefully understand and consider the question before he answers it.)

X Q. 91. Is it not clear to you that the patentee Deighton did provide means, good or bad, for delivering molten metal from four

blast furnaces into one receiving vessel *m* for the purpose of mixing molten metal to get a more uniform quality of metal, to be delivered to the converter?

A. The description of the patent and the drawing show so, but I do not see how it is possible for him to mix the iron in so small a receiving vessel.

— Q. 92. Then, if I understand you, the mixing of the metal from four furnaces in one vessel *m*, as stated in the patent, could not be advantageously carried out, because the vessel is too small as shown in the patent?

A. It being so small, and being a fixed one, it could only be applied to that one single converter.

X Q. 93. Do you see anything in the language of the Deighton patent to prohibit him from making the vessel *m* as large as he may please? In other words, does the patent contain any language limiting him to a vessel of any particular size?

146 A. As I read the patent it does not; but I think every one who has practical knowledge of iron and steel making would hesitate very much before fixing a receiver large enough to take molten iron for proper mixing from four blast furnaces. That receiver being fixed with a great weight of metal in it, when being tapped out at the bottom would be very dangerous and liable to run out after receiving one charge into the converter. The remaining metal in the receiver may be difficult to be kept in by botting it in. The weight of metal would come on the tap hole and is liable to break out.

(All after the words "it does not" is objected to as irresponsive and voluntary.)

X Q. 94. At the time of the Deighton patent, 1873, it was a common practice, was it not, in all steel works and foundries, to employ ladles of the kind that you employ for handling molten metal from the blast furnaces?

A. Not in England. I am not aware of any works using the direct methods.

Mr. DODGE: I am not speaking of methods, but of the ladles.

A. Our practice was to have cupolas fixed behind the converters and the metal run right into the converters, through a runner. A few years after that several works adopted the ladle.

X Q. 95. For years prior to the introduction of the mixer, it was a common practice in Europe and America, to make use of ladles for different purposes, was it not, substantially such ladles as you now use for charging your mixer?

A. That is so.

X Q. 96. So that if I understand you correctly, there is nothing new in using ladles to take the molten metal from one place to another, about a steel works or a foundry?

A. Yes, that is so.

147 X Q. 97. If it was convenient and the distance was short, you could carry molten metal through a runner or spout or

if the distance was greater, you could carry it from one place to another by ladle. Is that correct?

A. Yes, it is so, only one would always prefer taking it by ladle rather than through runners, which are more wasteful.

X Q. 98. You have been examined as to your knowledge of the Jones patent in suit. Do you find anything in the specification or claims of that patent, which requires the use of more than one converter in connection with the mixer?

A. The Jones mixer enables you to convey the metal in a ladle on a carriage to any converter, and in England we—there are several converter pits different from each other; therefore it is essential for us to have the metal conveyed in a ladle to them. This we could not carry out with a fixed receiver.

Mr. DODGE: I don't think Mr. Evans understood my question. I ask whether there is any language in the Jones patent which requires him to use more than one converter in his process?

Objected to as calling the witness to put a construction on the Jones patent, irrespective of the process, and therefore not proper cross-examination.

A. I understand from the wording of Jones' patent that the mixer is so placed as to convey to any converter.

(PLAINTIFF'S COUNSEL: If this question is asked as it appears to be, for the witness to place a construction upon the patent, he is instructed not to answer.

Defendant's counsel replies that under the statute patents are addressed to persons skilled in the art; that this witness has been produced and qualified as such a person; that he has been so interrogated in respect to the patent and his understanding of the
148 process. He is now asked further as to his understanding of the process described in the patent, whether it includes the use of the mixer with a single converter.

Witness is instructed that he may answer the question as it is now put.)

A. I understand by the reading of the Jones patent that he intended the metal to be delivered to a number of converters as he does not mention a single converter. It is not possible for a Bessemer plant to be worked continuously with a single converter.

X Q. 99. I will ask you as an expert in the art, whether you think that the use of a single converter with a suitable sized mixer, would be carrying out a different process from that you read in the Jones patent?

A. The only difference would be by having one converter in a plant, your plant would be standing a large portion of its time, as it is not possible to work with one converter continuously.

X Q. 100. What works have you personal knowledge of, in America and Europe, that are using the mixer?

A. In America, Edgar Thomson. I saw one in Chicago, but I didn't take any notice of it, and don't know in exactly what position it is worked; in England, Barrow Hematite Co., same as here-

tofore referred to, Bolckow Vaughan & Co., and Northeastern Steel Co. The Dowlais Company are also erecting one. In Europe, Dewendal's works, Hoerde in Germany, Oberhausen. I have not seen Dewendal's, but the others I have seen. The continental ones are all used in the basic process. Let me correct myself—there is also one used at Seraing, that is for the basic processes, in Belgium.

X Q. 101. Have you been instrumental in or interested in introducing the Jones process in Europe elsewhere than at your own works?

A. No more than my help and my son, who is in the syndicate for introducing this invention in Europe.

149 X Q. 102. Is it within your knowledge that a suit was instituted against your people at Barrow for infringing the British patent on the Jones process?

A. Yes.

X Q. 103. That suit did not go to the final hearing and decision by the court on evidence, did it?

A. No, it did not.

X Q. 104. In the Bessemer process it was a common practice long anterior to 1888 to mix molten metal from several cupolas or several blast furnaces in a ladle which was afterwards emptied into the converter, was it not?

A. It was so.

X Q. 105. Why did they draw the metal from several sources into the ladle for charging the converter?

A. To try and obtain a uniform mixture; but it is not possible to work the blast furnaces under those conditions, the converters having usually from eight to ten tons capacity, and you cannot possibly tap from the various furnaces such a small quantity as to give a proper mixture for the converter.

X Q. 106. Was it not a common practice anterior to the Jones patent to take several ladles, draw into these ladles from one furnace the metal it was convenient to take out, and then carry this series of ladles to another furnace and there draw into them more metal, and then after the ladles were filled in in this way with the mixed metal, to empty them one after another into the converter, certain of the ladles waiting, if necessary, until the converter is ready to receive the metal from them?

A. No, it was not so in England. The practice was to take a ladle on a carriage to the furnace, tap say half from one furnace and take it and tap the other half from the other furnace; exception of the Barrow Co, who used two and sometimes three ladles. This was taken to the Bessemer, but the arrangement was very inconvenient, as the metal cooled down in the ladle when it

150 waited for the converter. That is, assuming that one converter is charged, the other would have to wait until this charge is blown down. Our practice in England is very different to what it is here in the States, as we are not working so rapidly; therefore, taking a series of ladles is not conducive to economy.

X Q. 107. You have testified as to your understanding of the Jones patent, and that you are practicing at Barrow the process

described therein. Will you read the two claims of the patent, and state whether either or both of those claims describe what you are doing at Barrow?

(Objected to if it is intended to place a construction on the patent.

Defendant's counsel replies that he asks the witness to testify only in the same capacity in which he testified in chief on this point.)

A. During the time that I was at Barrow, we carried out the process mentioned in these claims as far as possible. Since I left, of course, I do not know.

X Q. 108. As a practical and experienced worker in metal, and after reading the patent as you have testified in chief, what do you understand to be the difference between the process described in the first claim and the process described in the second claim?

(Objection by complainant continued.)

A. As mentioned before, I am not an expert on patents or patent laws; but reading these claims, I consider they represent our mode of working when I was at Barrow.

X Q. 109. Is it the first or the second claim?

A. Both.

X Q. 110. Am I to understand that you do not see any difference between what is described in the first claim and what is described in the second claim? I am asking you as a person skilled in this art.

(Objected to by complainant's counsel as before.)

151 A. No, I stated before that in our mode of working we carried out the description of the first and second claims.

X Q. 111. Then as you understand the first and second claims, they are for the same thing, are they?

(Objection continued, and further objected to, as no such inference can be taken from the witness' previous answer.)

A. I did not say that they are the same, but that we carried out both in our mode of action.

X Q. 112. You are a practical steel worker. In answer to Mr. Bakewell, you testified that you had read the Jones patent, and that you worked the process. Now, I am asking you as a practical man, whether claim 1 means to you the same thing as claim 2, and if not, what the difference between them is.

(Objection continued.)

A. I don't see that there is any explanation, as the thing explains itself; I don't know what you want me to say.

X Q. 113. Does claim 1 mean the same thing to you as claim 2?

(Objection continued.)

A. I don't think, as a witness in this case, that I should define the claim 1 and claim 2, because as stated before, to my mind they

are clear enough, and don't want any explanation. I understood that the mode of working we carried out at Barrow carried out precisely what is said in these claims.

(Objected to as irresponsive.)

X Q. 114. If the claims are so clear you should have no objection to giving the court the advantage of your construction as a practical man. I will again ask you as a practical man, whether you understand the things described in the first claim to be the same as those described in the second claim.

152 (Objected to as the witness is not called as a patent expert to explain the constructions to be put on claims 1 and 2, and until the question is put in such a manner that the witness can understand it, and answer it technically, and not as a patent expert, that is taking the claims step by step and stating in what manner they carry out those steps at Barrow, as was practiced by him, witness is instructed he need not answer the question.

Notice is here given that a motion will be made to strike the entire deposition of this witness from the record because of his refusal to answer questions based directly upon and in the line of matters, regarding which he was examined in chief.)

Adjourned by mutual consent to Tuesday, October 5th, 1895, at 11 a. m.

TUESDAY, *October 5th*, 1895—11 a. m.

Met pursuant to adjournment.

Cross-examination continued without waiver of objection:

X Q. 115. What was the usual capacity of charging ladles such as referred to in lines 84 and 85, page 1, of the Jones patent?

A. That would depend upon the size of the converter. Each ladle will be tapped entirely into the converter. The average size of the converters in England is eight to ten tons each, with the exception of the basic. We at Bolckow use 15-ton converters.

X Q. 116. And the ladles correspond?

A. The ladles correspond.

X Q. 117. Are you aware that Mr. Jones received a separate American patent on the form of the mixing vessel shown in his process patent?

(Objected to as not proper cross-examination.)

A. I am not aware of that.

153 X Q. 118. You have been questioned in chief in respect to the Jones patent. What is your understanding as to the kind of mixer or the character of the mixer which you would have to use if you were building a plant to carry out the process as described in the patent? Do you understand that you would have to use any particular shape or kind of mixer?

(Objected to if the question is intended to place any construction upon the patent.)

A. We erected a mixer, as stated before, exactly the same as that described by Capt. Jones in his patent. And the ones I have erected at Bolckow differ a little in shape, but are practically the same all throughout.

X Q. 119. You misunderstand my question, I think. You have said in your direct testimony that you read the Jones patent. What I now want to know is, whether you consider it necessary to use any special form of mixer in order to carry out the process as you read it in the Jones patent?

A. My opinion is that the shape and form and mode of operation as described in the Jones patent is the best way of dealing with molten iron from the blast furnaces, and in proof of that, all that have been erected in England have been carried out on similar lines described in this patent, with the exception of a little variation in the form.

X Q. 120. Do you think that the mixer could be materially changed in form or construction from that shown in the patent and still carry out the Jones process with it?

A. It may in shape, but to a thorough commingling or mixing of the metal it is necesaary to give it a rolling or tilting motion.

X Q. 121. Am I correct in understanding from your testimony that some advantage could be gained by pouring the furnace charges together in a stationary vessel; but that greater advantage can be obtained when the vessel has a tilting or rocking motion?

154 A. You may have a slight advantage in tipping molten iron into a fixed receiver, but, as stated before, it is objectionable, very unpracticable and dangerous in operation, and in proof of that I want to explain that when I was at Ebbw Vale we had a fixed receiver placed similar to the Deighton receiver, in front of two cupolas. This receiver would hold a few tons more than the ladle mounted on a carriage in *in* front of the receiver to convey the molten iron from it to the converter. The first day this was carried out by tapping the receiver, the metal flowed into the ladle, the remaining portion of the molten iron remaining in the receiver could not be kept back by botting, the metal overflowed the ladle and covered it on the carriage, also filled the machine that was underneath the ladle carriage. That was the result, and eventually it was abandoned and taken out.

X Q. 122. When; immediately?

A. Yes, we found it was too dangerous to work, and consequently we took it out.

X Q. 123. Give the year.

A. About 1877.

X Q. 124. The converting process as practiced in England is much slower than in America, is it not?

A. That is so.

X Q. 125. Will you give the court some general idea as to the comparative length of time or as to the frequency of the blows or charges in England and America?

A. I should say, roughly, we get only about half of the output per converter for every twelve or twenty-four hours, that you do in America.

Redirect examination by Mr. BAKEWELL:

Q. 126. You have spoken of the basic process. What do you mean by this?

A. The basic process is for the elimination of phosphorus. Bessemer steel, I should say acid Bessemer steel, contains from
155 one-tenth of phosphorus downwards—that is a tenth of one per cent. The basic process is used to eliminate phosphorus from pig iron made from ores, which give one and a half to two and a half per cent. of phosphorus, and by this process the phosphorus is eliminated to the same analysis as that of the acid steel. This is done by lining the converters with a basic material and using lime in the charge to eliminate the phosphorus. The phosphorus is carried away in the slime with the lime. In the slag is phosphoric acid. This varies from eight to twenty per cent. of phosphoric acid and is crushed into fine powder and used as fertilizer.

Q. 127. Is there any special advantage in the use of the Jones mixer process in connection with basic converters?

A. Yes; the variation in silicon would materially affect the lining of a basic converter. In making basic pig iron the materials used vary considerably and give irregular quality of silicon. This is equalized by taking the various charges into the mixer. We can also desulphurize in the mixer by using manganese ore on one of the basic furnaces and taking the molten iron and pouring it into the mixer. The reaction takes place, the manganese combines with the sulphur and carries it away in the slag, and we derive greater benefit and greater economy by the use of the mixer in the basic process than the acid process.

Q. 128. What effect has an excess of silicon on the basic lining?

A. The silicon attacks it and carries it away rapidly in the slime.

Q. 129. You have stated that where you mix the metal from the cupola with the metal in the mixer you find it advantageous. You mean by this it improves the quality of metal in the mixer, or does it improve the quality of the metal from the cupola?

A. That depends, as stated before, upon what you charge
156 the cupola with; but in ordinary cases you get a better uniformity by taking the metal from the cupola into the mixer, which holds a large quantity of iron, which naturally gives you a more uniform product.

Recross-examination by Mr. DODGE:

X Q. 130. You do not find anything in the Jones patent, do you, as to the desulphurizing process you have described?

A. No, I do not.

X Q. 131. What do you find in the Jones patent suggesting the use of his process in making basic steel?

A. There is nothing. There is another patent of later date connected with the Jones mixer for making basic steel, by desulphurizing by manganese.

156*a* In the Circuit Court of the United States, District of Maryland. In Equity.

THE CARNEGIE STEEL COMPANY, LIMITED,
vs.
MARYLAND STEEL COMPANY OF BALTIMORE COUNTY and FREDERICK W. WOOD, Receiver.

Depositions taken on the part of complainant in the above-entitled case, May 23d, 1895, at the office of the Carnegie Steel Company, Limited, Bessemer, Pennsylvania, pursuant to notice.

Present: Mr. P. T. Dodge, for respondents, and Mr. J. K. Bakewell, for complainant.

Testimony of D. K. Nicholson.

DAVID KIRK NICHOLSON, being called as a witness on part of complainant being first duly sworn, deposes and says in answer to interrogatories put to him by Mr. Bakewell as follows:

Q. 1. Please state your name, age, residence and occupation.

A. David Kirk Nicholson; age, 29 years; residence, Wilkinsburg; occupation, mechanical engineer.

Q. 2. Were you ever employed at the works of the Maryland Steel Company, at Sparrows Point?

A. I was.

Q. 3. When, and for how long a time?

156*b* A. From May, 1891, to about May, 1893; about the space of two years.

Q. 4. What position did you occupy with the Maryland Steel Company?

A. I had charge of the rolling mills.

Q. 5. Did you see anything of the Bessemer department of the works while you were there?

A. I did.

Q. 6. State, if you know, what they did with the metal drawn from the blast furnaces at the Maryland Steel Company's works while you were employed there?

A. Part of it goes into the pig bed, part is taken to the converting mill, or Bessemer mill, and part in a receptacle called the mixer.

Q. 7. How many blast furnaces did they have at these works at that time?

A. Four.

Q. 8. How many were usually in operation at one time?

A. Three.

Q. 9. From how many of the blast furnaces was the metal taken to the mixer or receiver?

A. From all that were in operation.

Q. 10. What was this mixer or receiver?

A. It was a sort of a receptacle made up of steel plates, lined with firebrick; an enclosed place it was.

Q. 11. About how large was it?

A. Well, it held, as near as I remember, about 150 tons; was about 12 feet across by 15 feet long, and about 4½ or 5 feet deep, as I remember.

Q. 12. 150 tons of what?

A. Molten metal; it held that much molten metal; about that.

Q. 13. How was the molten metal taken from the blast furnaces to the mixer?

A. It was tapped out of the furnaces and run into a ladle, the ladle was hauled over to the converting mill, of Bessemer
156c mill, hoisted up by hydraulic power to the second floor—ten or twelve feet above—and poured into the end of the mixer.

Q. 14. Was this mixer stationary, or was it movable? Was it tiltable?

A. Tiltable; movable in one direction.

Q. 15. What was done with the metal after it was placed in the mixer?

A. The next thing done with it was to tap it out into the ladle at the other end opposite the pouring-in end—the tapping end of the mixer.

Q. 16. What was done with the metal after it was tapped from the mixer to the ladle?

A. Poured into the nose of the converter.

Q. 17. Did they ever use the cupola furnaces in connection with the metal taken from the mixer?

A. They generally did.

Q. 18. How did they use these cupola furnaces?

A. They generally tapped about half the quantity they wanted from the mixer, and then tapped the other half from the cupola; about half, as near as I could tell with my eye.

Q. 19. Into what?

A. Tapped it into the same ladle that they had previously put in that tapped from the mixer.

Q. 20. So that the ladle would then contain about half and half of metal from the mixer and from the cupola furnace?

A. It would.

Q. 21. What was the purpose of this mixer, if you know?

A. To obtain a more uniform metal.

Q. 22. Please describe more fully what you mean by this.

A. The analyses given from the blast furnaces are generally different, one has a certain analysis and another has another
156d analysis, certain ingredients in one case and certain in the other, and by putting them in the mixer they get an average metal.

Q. 23. That is, by putting the metal from several blast furnaces into the mixer you would get an average of the whole; is that correct?

A. Yes, sir.

Q. 24. Who was the manager of the Sparrow's Point works at the time you were there?

A. Mr. F. W. Wood was president, and acted as manager.

Q. 25. Did Mr. Wood have any special name for this mixer?

A. He called it a receiver.

Q. 26. What did the men call it?

A. Generally called it a mixer.

Q. 27. Did you ever hear Mr. Wood correct anybody in regard to its name?

A. To the best of my recollection, I remember him correcting a clerk once, named Horne, for calling it a mixer, and he said it was a receiver; that is the best of my recollection.

Q. 28. Had you ever seen a mixer for the same purpose prior to seeing the one at Sparrow's Point?

A. I did.

Q. 29. Where?

A. At Barrow-in-Furness, in England.

(Question and answer objected to as incompetent and immaterial.)

Q. 30. How did the operation of the mixer at Sparrow's Point compare with the operation of the mixer at Barrow-in-Furness?

Objected to.

A. Exactly the same, except that they had more blast furnaces at the Barrow-in-Furness works; that is, they used the metal
156e from more blast furnaces in Barrow-in-Furness than they did at Sparrow's Point; the purpose was exactly the same.

Q. 31. Who was superintendent or manager of the Barrow-in-Furness works?

A. David Evans. Mr. Edgar Richards showed and explained it, and took charge of the converting mill.

Q. 32. Were you informed where they got their mixer from at Barrow-in-Furness?

Objected to.

A. Mr. Edgar Richards had previously been employed at the Edgar Thomson works, and when explaining it to me said he got it from the Edgar Thomson works.

Q. 33. Do you mean the Edgar Thomson works near Pittsburg, Pennsylvania?

A. Yes, sir.

Objected to.

Q. 34. Did you ever see the mixer at Sparrow's Point in operation?

A. I did.

Q. 35. How long while you were at Sparrow's Point was it in operation?

A. I can't exactly tell, but I am quite sure, at least eighteen months. I can't tell the date for I never kept any record.

Q. 36. I hand you this blue print and ask you to state if you recognize it.

A. I recognize here the blooming mill, converting mill and the rolling mill, on the plan here of the Sparrow's Point works of the

Maryland Steel Company. This appears to be a general plan of the whole works.

Q. 37. Is the mixer you have spoken of shown on that blue print?

A. Yes; it is marked with the red letter "M," also an "S" at the tapping end of the mixer.

Q. 38. Is the cupola furnace shown on that blue print?

A. It is.

156f Q. 39. Please mark it with the letter "C."

A. I have done so.

Q. 40. Is the ladle by means of which the metal is brought from the blast furnace to the mixer shown in the blue print?

A. It is.

Q. 41. Please mark it with the letter "B."

A. I have done so.

Q. 42. Is the ladle by which the metal is taken from the mixer to the converter shown in the blue print?

A. It is marked with the red letter "X."

Q. 43. Is the converter shown in the blue print?

A. It is; it is marked with the red letter "V."

Q. 44. How far away was the receiver from the converter at the Sparrow's Point works?

A. From recollection?

Q. 45. State from your recollection.

A. About 50 feet; of course, there were two converters, and it would be a little further from the furthest one than the nearest, but about 50 feet.

Q. 46. How many mixers were there?

A. One in operation and one being constructed.

Q. 47. While you were there?

A. While I was there.

Q. 48. Is the relative arrangement of the mixer and converters shown in the blue print?

A. It is, on the left-hand side at the top of this sheet.

Blue print offered in evidence and marked "Complainant's Exhibit Print of Sparrow's Point Plant."

Q. 49. I hand you another blue print, and ask you if you know what it represents?

A. It represents the details of the mixer, to the best of my knowledge and belief.

Q. 50. Please mark the mixer as it is shown on the blue print with the letter "M."

156g A. I have done so in both places—marked the elevation.

Blue print offered in evidence and marked "Complainant's Exhibit Print of Sparrow's Point Plant No. 2."

Q. 51. How often was the mixer at Sparrow's Point works filled and emptied during the year?

A. Its work was continuous during the week, it was emptied on Saturday afternoon and started to be filled Monday morning, the

following Monday morning, as a general thing, unless some break-down in the works.

Q. 52. Then during the week there was at all times molten metal contained in the mixer?

A. Yes; unless, as I stated before, some serious break-down.

Q. 53. How did they charge to the mixer from the blast furnaces—altogether from one blast furnace during one week, or how?

A. From all the blast furnaces.

Q. 54. At the same time?

A. At the same time; yes, sir.

Q. 55. What time did they generally tap the blast furnaces at the Sparrow's Point works?

A. They arranged to tap at different times; blast furnaces generally tapped four times in 24 hours, that is, at different periods in 24 hours; rarely two furnaces tapped at exactly in the same hour, but at four periods during the 24 hours all the furnaces are tapped once, unless something wrong with the operation of them, or an accident or something.

Q. 56. You say there were three blast furnaces kept in operation at a time?

A. Yes; to the best of my knowledge, there were.

Q. 57. When they tapped from No. 1 what did they — with the metal?

A. Either cast it into the pig bed or took it to the mixer; generally, however, taken to the mixer.

1564 Q. 58. When tapped from No. 2 what did they do with it?

A. Either cast it into the pig bed or took it to the mixer; generally, however, taken to the mixer.

Q. 59. And when tapped from No. 3?

A. The same as from No. 1 and No. 2.

Q. 60. Then there would be successive charges from the blast furnaces placed in the mixer, is that correct?

A. If you call the metal that comes out of the blast furnace a "charge." The product of the furnace was placed in the mixer.

Q. 61. Was the mixer at Sparrow's Point mounted on trunnions?

A. In a general sense it worked as if on trunnions, though it rolled on rollers underneath it, as shown in the blue print; it was tilted as if it went through the same motion.

Q. 62. What year did you go to Sparrow's Point to work there?

A. 1891.

Q. 63. Do you recollect the month?

A. May.

Q. 64. How soon after you went there was the mixer put into operation?

A. I went there in the spring and in the following fall it was put into operation, to the best of my recollection.

Q. 65. The fall of 1891?

A. Yes; the works started on the first day of August, 1891.

Q. 66. How soon was the mixer used?

A. Shortly after that; I don't remember the exact number of days, but shortly after that.

Q. 67. Have you any interest in the results of this suit?
A. I have none.

156*i* Cross-examination, without waiver of objection, by P. T. DODGE, Esq., counsel for respondents:

X Q. 68. You are now in the service of the Edgar Thomson Company, are you?
A. Yes, sir.
X Q. 69. And the Edgar Thomson works are the property of the Carnegie Steel Company, Limited?
A. Yes, sir.
X Q. 70. If I understand you correctly, the real purpose of the mixer at Sparrow's Point was for mixing the molten metal from two or more smelting furnaces to get a more uniform quality of metal?
A. Yes, sir.
X Q. 71. And that was the primary and principal object, as you understood it?
A. Yes, sir.
X Q. 72. So far as obtaining a uniform or average quality of metal, does it make any difference how, or by what means, the successive charges or supplies of molten metal are delivered into the mixer or receiving vessel?

(Objected to, as the witness had not been called as an expert, but merely to describe the operation of the mixer at Sparrow's Point, while there employed; the question is, therefore, incompetent and irrelevant.)

A. I don't exactly understand that question. There is no possible way of carrying it only carrying it in a vessel. I don't see how you would get it there unless you carried it in a vessel, or some sort of ladle; but it would not make any matter whether conveyed in a balloon or by a locomotive; the way of transportation would not matter.
X Q. 73 Am I correct in understanding you to say that at Sparrow's Point it was the custom generally to draw the metal from the mixer, and thereafter add to the metal thus drawn additional metal from one or more cupolas before the mixer was carried to the converter?
A. It was generally the custom.
156*j* X Q. 74. Then it was not the custom at Sparrow's Point to deliver metal from two or more blast furnaces into the mixer, and then deliver this mixture unchanged to the converter?

(Objected to, as the word "unchanged" is indefinite.)

A. It was not the custom.
X Q. 75. At the Sparrow's Point works it was not the custom, was it, to mix the metal from the blast furnaces in a mixer, and then conduct it to the converter without the addition of other metal or material?
A. More metal was put in but not other metal; it wasn't a differ-

ent metal; pig iron from the cupola; additional metal was generally put in from the cupola, but it was all pig iron.

X Q. 76. But it was not the custom at the Sparrow's Point works to mix the charges from the blast furnaces in the mixer, and then charge the converters solely with metal from the mixer?

A. It was not.

X Q. 77. What was the capacity of an individual blast furnace at Sparrow's Point?

A. I don't exactly know the capacity. I know they made about 190 tons in twenty-four hours.

X Q. 78. From each furnace you mean?

A. Yes, sir; from each furnace. I don't think they were run to their full capacity, from my knowledge of other furnaces.

X Q. 79. What was the usual quantity of metal delivered from the mixing vessel—mixer, you call it—to the converter as one charge?

A. About eight tons from the mixer, and about eight tons from the cupola—making a heat of from 15 to 18 tons. The capacity of the converter was 18 tons.

X Q. 80. Am I correct in understanding that there was simply a mechanical mixing of the blast-furnace charges in the mixer?

156*k* A. There was.

X Q. 81. To distinguish from any chemical mixing?

A. The chemical ingredients combined, that is, say, $\frac{6}{100}$ and $\frac{3}{100}$ averaged $\frac{4}{100}$.

X Q. 82. But no chemical reaction?

A. No.

X Q. 83. Have you read, or are you familiar with the complainant's Jones patent under which this suit is brought?

A. I am not familiar with the patent under which it was brought; I didn't even know there was a patent.

X Q. 84. Are you able to say to what extent the quantity of metal in the mixer at Sparrows Point varied during the ordinary daily process?

A. Well, with regard to sulphur——

X Q. 85. The question is the amount of metal in the mixer?

A. Well, I hardly think there was ever a variation of more than 25 to 30 tons—possibly 50—but not as a general thing; I should say 25 to 30 tons as I remember.

X Q. 86. I suppose the capacity of the mixer or receiver would naturally be controlled by the number of blast furnaces in use, the frequency with which their metal was to be delivered to the mixer, and the frequency with which it was necessary to charge the converters from the mixer?

(Objected to as a hypothetical question, involving other plants than the one at Sparrows Point.)

A. It would. Of course, several other mixers would answer the same purpose; the capacity of one might not be enlarged, but several would attain the same end.

X Q. 87. You have mentioned one advantage attending the use

of the mixer; was it not another advantage that it served as a place of storage for the molten metal, so that the entire contents of the blast furnaces could be tapped at once, when ready, and the furnaces recharged without delay?

(Objected to as incompetent.)

156*l* A. Of course it would answer as a place of storage, but not in my judgment, as an economical method, because it could be tapped and held in these ladles as carried on previously to having the mixer; or what would be the use when it could be poured direct into the converter?

X Q. 88. In the previous blast-furnace ladles to which you refer, was it customary to have them contain at one time metal from two or more blast furnaces?

A. It may have been; I don't know whether it was or not; it is quite probable they did.

X Q. 89. These old blast-furnace ladles—what was their capacity as compared with that of the blast furnaces with which they were used?

A. Well, I should say a ladle would hold probably 30 or 35 tons, and a furnace at each tap would cast, say, 50 or 60 tons.

X Q. 90. At Sparrows Point was it the practice to observe some special order or arrangement for the delivery of the blast-furnace metal to the mixer, or were the furnaces emptied into the mixer whenever ready to tap?

A. Discharged it whenever they got ready. Of course, the tapping of the furnaces was generally at the regular time for tapping, unless it was working badly.

X Q. 91. And the fact was, that whenever a furnace was ready for tapping they tapped it in?

A. Yes, didn't hold back because it wasn't the time for it.

X Q. 92. Now, at Sparrows Point, it was the custom to use the mixer vessel to receive the molten metal from two or more blast furnaces to get a better average metal which was more suitable for making Bessemer steel, or metal of uniform quality, than the unmixed metal would have been?

A. Well; there is another side to it.

X Q. 93. Well, is that true as far as it goes?

A. Part of that I could say yes to, and part not. It en-
156*m* abled them to use a poor grade of iron with a better grade and make the whole business pass muster. I should think that would have the greatest weight—to enable them to use a poor grade of iron with a better grade and get an average result that would pass muster.

X Q. 94. When was it that Mr. Wood corrected Horne as to the name of the mixer or receiving vessel?

A. I can't remember that day; it was one morning in the Bessemer office—the office between the Bessemer and bloom mill—I don't remember the date.

X Q. 95. What gave rise to that correction by Wood?

A. He was questioning him on the result of the night before.

This clerk kept a record of the operation, or at least worked on the records.

X Q. 96. At Sparrows Point did your duties require your attendance in or about the converting department?

A. They did at times.

X Q. 97. What experience, if any, have you had previous to your employment at Sparrows Point in connection with steel plants, foundries or other establishments in which the working of molten metal was carried on?

A. Never in any where molten metal was carried on. I was five years in the same company's works in Steelton plant. Previous to that I studied the theory of metallurgy of iron and steel.

Redirect examination by Mr. BAKEWELL:

R. D. Q. 98. Do you know why they used the cupola furnace in connection with the mixer at Sparrows Point works?

A. I do. They started the blast furnaces some time before the steel works were started, and they had a large quantity of pig iron on hand, I think a millon dollars' worth.

R. D. Q. 99. Then they merely used the cupola furnace to work up this pig metal they had in stock?

A. Yes, sir.

156*n* By Mr. DODGE:

R. X Q. 100. State how long that lasted. Was it all the time you were there?

A. Yes; it was during the eight months I was there the mixer was in operation.

By Mr. BAKEWELL:

R. D. Q. 101. How much metal was cast at each tap from each of the blast furnaces at Sparrows Point?

A. I should say about fifty tons. That, however, I only answer in a general way; never took interest in it to find out or anything of that sort.

R. D. Q. 102. In charging the blast furnaces at Sparrows Point works, did they use different grades of material purposely in the different blast furnaces, or the same material in each of the blast furnaces?

A. As far as I know they used the same in each and all of the blast furnaces.

It is hereby stipulated that the blue prints "Complainant's Exhibits of Sparrows Point Plant No. 1 and No. 2" are correct representations of the plant of the respondents.

Testimony of Clarence M. Tolman.

CLARENCE M. TOLMAN, called on the part of complainant, being first duly sworn, deposes and says in answer to interrogatories put to him by Mr. Bakewell, as follows:

Q. 1. State your name, age, residence and occupation?

A. Clarence M. Tolman; aged 30; residence, Wilkinsburg; occupation, electrical and mechanical engineer.

Q. 2. Were you ever employed at the works of the Maryland Steel Company, at Sparrows Point?

A. I was.

Q. 3. Between what periods of time?

A. Between the end of January, 1891, and May, 1893.

Q. 4. What was your position at the Sparrows Point works?

156*o* A. I had charge of the electrical apparatus and the electrical construction work of the Maryland Steel Company.

Q. 5. Do you know whether or not, during the time you were employed at the Maryland Steel Company, they had a mixer for receiving the molten metal from the blast furnaces?

A. They had an apparatus for receiving the molten metal, yes, sir.

Q. 6. How many blast furnaces did they have at the Sparrow's Point works during the time you were there?

A. There were four blast furnaces there.

Q. 7. How many were in operation at one time?

A. When I first went there there was but one in operation, afterwards two, and finally three.

Q. 8. How long after you went there before they had three in operation?

A. Well, that I can't state exactly; I should say, perhaps after I had been there a year.

Q. 9. From which of these blast furnaces was the metal taken to the mixer?

A. From each of the three that was in operation.

Q. 10. After the metal was placed in the mixer what was done with it, according to your observation?

A. After it was placed in the mixer?

Q. 11. Yes. What was done with it, according to your observation?

A. Why, at certain times, it was poured out of the mixer or apparatus into a ladle mounted on trucks and taken from there to the charging floor of the converting mill, and poured into the converters.

Q. 12. Did you ever have occasion to particularly observe the operation of this mixer? Did you ever have any work to do about it?

A. I had some work in connection with the mixer, yes, sir.

Q. 13. What was this work?

156*p* A. I applied a motor for tilting the ladles of molten metal when brought from the blast furnaces into the mixer.

Q. 14. Are there any cupola furnaces near the mixer, do you recollect?

A. There were.

Q. 15. When you saw the mixer in operation and the metal from the mixer poured into the ladle to go to the converter, did they take metal from the cupola furnace also?

(Objected to as leading.)

A. It is my impression that they took metal from the cupolas also.

Q. 16. You are not sure about that, are you?

A. I am not absolutely sure; no, sir.

Q. 17. Look at the blue prints I hand you, "Complainant's Exhibit Print of Sparrow's Point Plant No. 1 and No. 2," and state if you know what the part marked "M" represents?

A. The part marked "M" represents the equivalent of the apparatus which is here called a mixer.

Q. 18. That is, you mean at the Edgar Thomson works it is called a mixer?

A. Yes, sir.

Q. 19. What was it called at the Sparrow's Point works?

A. It was there called a receiver, I think. I can't swear to that, but that is as my memory serves me; I have the word "receiver" in my mind, but where I got it I don't know.

Q. 20. In these blue prints do you know what the part marked "X" is?

A. The part marked "X" is one of the ladles for handling the molten metal in the different stages of process.

Q. 21. How do you know that the part marked "M" is the equivalent of what is here called the mixer; I mean, do you recognize ever having seen such an apparatus at Sparrow's Point?

156*q* A. Oh, yes, I saw the apparatus marked "M," or something very similar to it at Sparrow's Point.

Q. 22. Have you ever seen these drawing- or had them explained to you before these questions were asked you?

A. No; I may have seen those drawings at Sparrow's Point, but not to have them explained to me.

Q. 23. What does the part marked "B" represent?

A. The part marked "B" represents one of the converters into which the metal was poured and taken to the part marked "M."

Q. 24. What does the part marked "C" represent?

A. "C" represents one of the cupolas which were situated near the mixer.

Q. 25. When at work at Sparrow's Point did you know the purpose of the mixer or receiver "M"?

A. I did.

Q. 26. Please state what you understood to be the purpose at that time?

A. I understood it to be for the purpose to equalizing the quality of the metal obtained from the blast furnaces.

Q. 27. Do you recollect about what year it was that you put the motor on the ladle, as you testified?

A. I should think it might be, perhaps, in the fall of 1892.

Q. 28. Had you seen the mixer or receiver in operation prior to that?

A. I had.

Q. 29. Do you recollect about when the receiver or mixer was put in use at Sparrow's Point?

A. I can't say to be definite about that. I went there in January, 1891. It was possibly in the fall of 1891, or spring of 1892.

Q. 30. That it was put in use?

A. Yes.

Q. 31. Have you any interest in the result of this suit?

156*r* A. I have none.

Cross-examination by P. T. DODGE, Esq., counsel for respondents:

X Q. 32. You are now in the service of the Edgar Thomson Steel Company?

A. Edgar Thomson steel works of the Carnegie Steel Company, Limited, yes, sir.

X Q. 33. If you know, how often was the mixing vessel at Sparrow's Point supplied with molten metal, and in what quantities at each time?

A. I should say that, possibly—there was nothing regular about the putting of metal into the mixer—possibly every five or six hours ladles were brought over from the blast furnaces, and I should think the quantity was, perhaps, twelve or fifteen tons.

X Q. 34. In each ladle?

A. Yes, sir, each ladle.

X Q. 35. How did you learn the purpose of the receiver or mixing vessel at Sparrow's Point?

A. That is a question that is hard for me to answer. I suppose that I learned it by seeing it operated and by hearing it talked about, though by whom, there I can't say.

X Q. 36. Is it not a fact that that receiver or mixing vessel at Sparrow's Point had another important office—that of serving as a receiver or place of storage for the molten metal so that the blast furnaces could be recharged and run without interruption?

A. From my knowledge of metallurgy it seems to me that the operation of this apparatus had nothing to do with the running or charging of the blast furnaces; they could be run or charged without reference to this apparatus.

X Q. 37. At Sparrow's Point did not the mixer or receiver serve as a place of storage for the molten metal delivered from the blast furnaces so that the blast furnaces could be tapped and

156*s* emptied whenever ready, and the accumulated molted metal held in reserve for further use as demanded?

(Objected to as multitudinous.)

A. It seems to me that that question is a repetition of the other

one, Mr. Dodge. The mixer, according to the ordinary accepted definition of the word storage, the metal from the different blast furnaces was placed in the mixer. I told Mr. Bakewell that. As to the latter part of the question, I think so, yes, sir.

(Question is also objected to as not calling for a plain statement of facts, and calling for the purpose of the storage as well as to whether there was such storage or not.)

X Q. 38. At Sparrows Point the molten metal was delivered from several blast furnaces into one large vessel or receiver in which it accumulated, and from this store of molten metal a portion was drawn from time to time for use, is that correct?

A. That is correct.

X Q. 39. The plant at Sparrows Point was a Bessemer plant, was it?

A. Yes, sir.

X Q. 40. And it had a receiver or receptacle for mixing the molten metal from two or more smelting furnaces to get a more uniform quality of metal?

A. That is the way I understand it, yes, sir.

X Q. 41. With what were the blast furnaces charged at Sparrows Point?

A. They were charged with various kinds of ores, with coke and limestone, which is the usual blast-furnace product, as I understand. I understand that blast furnaces have always been charged in that manner.

X Q. 42. Am I correct in understanding that in the receptacle or mixing vessel at Sparrows Point there was simply a mechanical com-ingling of the charges of molten metal as distinguished from any chemical union or treatment?

156*l* A. Well, that is going into the thing, Mr. Dodge, rather deeply for me. I don't understand everything that goes on in this receiving vessel, as I say. The idea I have gained was that the object of the receptacle was to equalize the quality of the metal rather than for any mechanical or chemical process. I can't say; I have my ideas about it, perhaps, but I can't say.

X Q. 43. But, so far as you observed at Sparrows Point, there was nothing added to the molten metal in the mixer, and no treatment of the molten metal carried on in the mixer, was there?

A. No, sir. As I understand the ordinary use of the term there was no treatment carried on in the mixer.

X Q. 44. Was it not the general practice, as you observed it at Sparrows Point, to mix with the metal delivered from the receiver or mixer an additional quantity of molten metal from the different sources before the metal was conducted to the converter?

A. I have the idea that that is the case, though I don't know as I could swear to that direct fact. I have the idea in my mind so.

X Q. 45. What do you understand to be the purpose of the ladle marked "X" in the exhibit drawings?

A. The ladle marked "X" was for the purpose of conveying the molten material from the mixer to the charging floor of the con-

verting mill or Bessemer mill, where it was poured into the converters.

(Signatures waived by consent of counsel.)

(Counsel for complainant offers in evidence certified copy of letters patent No. 404,414, for improvement in method of mixing molten pig metal, granted to William R. Jones, on the 4th of June, 1889, same being copy of the patent in suit.

156*a* Also, certified copy of an assignment of said letters patent No. 404,414, from Harriet Jones, executrix of the said William R. Jones, to Carnegie Brothers & Co., Limited. It is hereby stipulated that the certified copy hereby offered may be used to the same effect and purpose as if the assignment itself were so offered.)

Adjourned.

157 Circuit Court of the United States, District of Maryland.

CARNEGIE STEEL COMPANY, LTD., *vs.* MARYLAND STEEL COMPANY OF BALTIMORE County and Frederick W. Wood, Receiver. } In Equity. Patent No. 404,414.

Depositions taken on the part of the defendant in the above-entitled case, pursuant to notice and agreement of counsel, beginning at 11 a. m. on the 9th day of January, 1896, at the office, No. 208 South Fourth street, Philadelphia, Pa.

Appearances: J. K. Bakewell, for complainant; P. T. Dodge, for respondent.

Testimony of John R. Whitney.

JOHN R. WHITNEY, being duly sworn as a witness on behalf of the defendant, deposes and says, in answer to interrogatories proposed to him by P. T. Dodge, counsel for defendant, as follows, to wit:

Q. 1. State your name, age, residence and occupation.

A. John R. Whitney; 67 years old next birthday; residence, Bryn Mawr, Pa.; I have no special occupation at present; I withdrew from the firm about two years ago; I was formerly senior member of the firm of A. Whitney & Sons, from 1865 to December, 1893.

Q. 2. What was the business of A. Whitney & Sons, and where was it carried on?

158 A. The manufacture of chilled car wheels; carried on in Philadelphia, Callowhill street, between Sixteenth and Seventeenth streets.

Q. 3. State, in a general way, how long Whitney & Sons have been engaged in that business, and the extent of their business?

A. The business was begun by my father; I think it was in 1847; it is still continued by my brother. The extent of the business has been from 50,000 to 70,000 wheels a year, in general terms.

Q. 4. Of what material are car wheels made?

A. Pig iron.

Q. 5. Please say whether or not, it is necessary to maintain a uniformity in the quality and character of the pig iron employed?

A. It is a necessity for anything to wear—you want to get as near a uniform quality as possible to obtain a uniform wear.

Q. 6. Please state whether the Whitney Company employed any means for securing a uniformity in the character of the molten pig iron used in its operations, and, if so, describe in your own way what was done?

A. That covers a large field; in the first place, the mixture generally used consisted of a great variety of irons from different furnaces—some of them possessing high chilling qualities, some low, some pig metals from the furnace, some old wheels broken up. We never introduced iron into the mixture without first testing that iron by itself, the great variety of tests to ascertain its special individual character. Having ascertained that for each iron we used in the mixture we mixed them in the proportion which our experience dictated, so as to produce the best results. That was the first step towards securing uniformity; that is, I mean by mixing them we regulated the proportion and amount of each iron to be used in the mixture; that is, we would have 100 pounds of
159 this iron, 200 pounds of that iron, 300 of another, perhaps 50 of another, and so on; that was determined in the office. We formed that mixture of iron from our experiments. Then that mixture was weighed in draughts of about 2,000 pounds each, each draught consisting of its proper proportion of these several different irons, as I have named—100 pounds of one, 200 of another, etc. Then those draughts were charged into the cupola upon a bed of coal between each draught of iron until the cupola was full, when the blast was put on as this iron melted. I may say, in passing, that it was charged when we were running full heats in three cupolas especially set apart for melting wheels. As it melted in these three cupolas, a spout leading from each cupola conducted it into the large ladle which stood in front of them. That ladle held from 12 to 15 tons of molten iron according to the way in which it was lined up with firebrick. When the ladle was nearly full we began to pour from it into smaller ladles, each one of which held enough for one wheel; if it was an ordinary sized wheel it held enough for one wheel, and if the wheels were smaller ones it held enough for two or three. As that drew the molten iron from the ladle and the iron continued to melt, the ladle was constantly being filled from the cupolas, and it was kept full until all the iron charged in the three cupolas was melted and the bottoms dropped. Then the iron was continued to be poured out of the large ladle until it was all used, those two methods making the uniform mixture; that is, we mixed it in a solid state, first by our charges and then in the molten state in the large ladle.

Q. 7. In the ordinary course of operations in the Whitney works, what amount of metal was passed through the cupolas and into the large ladle in the course of a day's operation?

A. We melted from 50 to 80 tons of iron a day, according to the state of business; and all of it went into the cupolas, and from the cupolas into the large ladle.

160 Q. 8. Will you state what the principal advantages of using the large ladle to receive the molten metal from the cupolas was?

A. It secured a better mixture of the iron. Do you want me to describe in detail?

Q. 9. A little more fully.

A. As the mixture was charged into each cupola, as I have stated, it was made up of irons from various furnaces, some iron having one quality and some another. As it is melted in each cupola, it did not all melt at the same time, and if we had drawn it directly from the cupola into the small ladles from which we poured the wheels, one wheel might have been poured out of very hard iron, another wheel out of very soft iron, and so every shade between. There would have been no uniformity in our work. But by taking it from the three cupolas, all melting the same charges of iron, and collecting them in a molten state, the inequalities of melting were all overcome and a uniform product produced.

Q. 10. Am I correct in understanding that at the Whitney works your three cupolas *where* charged and tapped at all reasonable intervals throughout the working day, and *and* that when their charges were in proper molten condition they were tapped out into the one large ladle, each cupola being tapped whenever it happened to be ready?

A. They were generally tapped very simultaneously. The iron melted very uniformly as a rule in each cupola, so that once enough iron for a wheel was melted in each cupola it was drawn out into a ladle. There were generally enough for three wheels drawn at a time into the large ladle; about a wheel would melt in each cupola, and the three cupolas were tapped about the same time.

Q. 11. State in a very brief way approximately how often those cupolas were tapped?

A. I suppose it took perhaps ten or fifteen minutes between each tap; we began to tap, generally, say about one o'clock, and
161 would be done, generally, between five and six. There would be twenty-five to thirty tons of iron in each cupola.

Q. 12. Am I correct in understanding you that at the Whitney works you tapped at intervals of fifteen minutes, more or less, through the day, from the three cupolas into a large ladle holding from twelve to fifteen tons, so that these various charges from the different cupolas and different charges from the same cupola were mixed together in a molten condition in the large ladle?

Objected to as unwarranted and leading, witness not having stated anything about different charges in the same cupola.

A. That was what I tried to make plain. I stated that the different charges were put into each cupola with a layer of coal between each charge, and, as they were melted, they flowed into this large ladle from each cupola. Of course, as each charge came down it

would be mixed in the ladle the same as the charges from all the cupolas.

Q. 13. During your operations, what quantity of the mixed molted metal was commonly carried in a large ladle?

A. It would vary from 10 to 15 tons until it was all drawn out, and then, as a matter of course, as you got to the end, there would be nothing.

Q. 14. But during the day, while there was this large quantity of molten metal in the large ladle, you were drawing into it at random, the molten metal from the cupolas and drawing off the mixed molten metal into the small ladle for foundry use; is that correct?

A. Yes, sir.

Q. 15. How long were you connected with the Whitney works, and what means had you for knowing personally as to their operations—that is, whether you took an active part in the business or not?

A. I went into the works when I graduated from school,
162 and have been there ever since, until I withdrew from the firm in 1893; from 1848 to 1893. During most of that time I had entire charge of the mixing of the iron and the handling of it.

Q. 16. Please examine the model now before you, and state, if you know, what it represents?

A. It looks very much as if it were modelled from the three-wheeled cupolas and ladle, in the foundry of A. Whitney & Sons, the same one that I referred to in my testimony.

Q. 17. Please say whether you consider this model a fair and truthful representation of the cupolas, spouts and ladles as used in the Whitney works, and to which you have testified?

A. Yes; a very fair representation of them, just as I have testified to.

Q. 18. For the information of the court, will you please state what the parts lettered A, B, C and D are?

A. The part A represents the cupola; there are three of them, all alike; the part B is the spout or runner that takes the molten metal from the cupola to the large ladle; the part C is the large ladle standing in front of the three cupolas; D represents a small ladle, from which the individual wheels are poured.

The model referred to by the witness is offered in evidence and marked by the examiner "Defendant's Exhibit No. 1, Model Whitney Works."

Testimony of this witness regarding the model referred to and offered in evidence, objected to as incompetent, for the reason that no reference is made to it in the answer.

Q. 19. State when the plant represented by Exhibit No. 1 was established by the Whitney Co., and whether it has continued in use to the present time?

A. I think it was established about 1853, when we moved into the works on Callahill street, and, with some slight modifications,

the general principles have been in operation ever since, and are still in operation.

163 Q. 20. Please state whether, from the time of this installation in 1853, that Whitney plant has contained the three cupolas, and the large mixing ladle receiving molten metal from the cupola?

A. Yes, sir.

Q. 21. Please say whether or not the plant of the Whitney works was changed in location or rearranged at any period; if so, when and what was done, briefly?

A. I think it was in 1856 the location of the cupolas was changed. Prior to that time, the foundry ended in a line with the middle wing of the present construction and the cupolas stood across the end from one side of the foundry to the other. At that time the foundry was lengthened up to Seventeenth street, and the cupolas were changed from across the foundry to one side of the foundry, directly opposite the chimney. It was changed around, so that the top flue would connect directly with the chimney to carry the gases from the cupola. There was no change in the details; that is, no essential changes. We made some modifications in the arrangement of the blast or something of that kind.

Q. 22. Please examine the three sheets of drawings now handed you (three drawings handed witness), and state, if you know, where they came from and what they represent?

A. These all came from A. Whitney & Sons' car-wheel works; they were brought here by myself, and were drawn by myself.

Q. 23. Will you state when and for what purpose you made these drawings?

A. Those that are dated show the date when they were made. They were made for the purpose of erecting the large ladle and the appliance to it.

Q. 24. One of these drawings is dated November 13th, 1857; the other two are apparently without date. Can you state approximately when the undated drawings were made?

161 A. Not with any accuracy. I presume some time in '57 or '58. That was the time when we made these changes, and I suppose they were all drawn about the same time.

Q. 25. Are you able to recognize and positively identify those three drawings as having been made about the time of the change in the plant?

A. Yes; as near as my recollection serves, and from the character of the drawing, I presume that I made them at that time; they have not my name on, but my style of work is there, and the handwriting is mine. The drawings have been lying in the drawer where we keep all our drawings at the Whitney works until I brought them away today.

The three drawings referred to by the witness are offered in evidence and marked respectively "Defendant's Exhibits Nos. 2, 3 and 4, Working Drawings, Whitney Plant."

Former objection continues.

Q. 23. Referring to the drawing "Defendant's Exhibit 2," please state what the parts marked A, B, C represent?

A. A represents 3 cupolas, B represents three spouts—one from each cupola—C represents the large ladle into which the spouts emptied.

Q. 27. Please say whether or not this drawing, Exhibit 2, is a fair representation of the plant as used at the Whitney works in 1857, or ther-abouts, regarding which you have testified?

A. In the general features it is, and the same is there today.

Q. 28. Referring to the drawing, Defendant's Exhibit 4, please say what it represents?

A. The large ladle has an arrangement for turning or moving it. It was originally on wheels, as shown in this drawing. It now stands on firm, solid foundation. The first ladle was made so it could be moved from side if needed.

165 Q. 29. I understood you to speak of the ladle having at one time two discharge pipes at different levels; what have you to say on this point?

A. It was an experiment tried for the purpose of taking the iron from different levels, with the supposition that we would get a different quality of iron, but it was found not to be so, and it was troublesome, and the spouts were taken off, and we poured directly from the top of the ladles, getting a uniform mixture just as well from the top as we would from the bottom. That change was made somewhere about '55 or '60. It was a great many years ago. The two spouts have not been in use for fifteen or twenty years.

Q. 30. Please say whether or not the use of the large ladle, into which you drew molten metal from the several cupolas, did or did not answer the purpose of giving you a uniform quality of cast iron?

A. It gave us the most uniform quality it was possible to obtain.

Q. 31. I will ask you to state a little more fully as to the practice in the Whitney works of filling the large ladle—whether you kept it full or partly full by filling it through the day, or whether it was simply filled once and completely emptied?

A. It was filled as fast as it was emptied. We began to tap, say, about 1 o'clock. We continued to tap without pouring out any iron until the ladle was full. Then we drew out into the small ladle as it was required for each wheel. At the same time we kept filling into the large ladle new iron as it was melted in the cupola, so that the ladle was kept full until all the iron in the two or three cupolas as we were running, was melted, it being filled as fast as it was drawn out. When all the iron of the three cupolas was melted for the day, with nothing to refill it, then of course it began to grow less and less; but say we began to melt and fill it at 1 o'clock,

166 and got through melting at 5 o'clock, it would be kept full from one till half past four; then it would begin to diminish the last half hour it began to pour out.

All the testimony of the witness is objected to for the reason that the alleged prior use is not set up in the answer.

Cross-examination, without waiver of objection:

X Q. 32. How many men were employed doing the tapping from these three cupolas?

A. One at each cupola.

X Q. 33. About how many men drawing from the large ladle?

A. One man turned the ladle, and there would be half a dozen, sometimes taking small ladles away as they were filled.

X Q. 34. What was the size of your small ladles?

A. They would hold about 600 pounds molten metal.

X Q. 35. Was the use of these three cupolas with the large ladle open and public?

A. Yes.

X Q. 36. Do you know whether this arrangement was used at any other foundry beside yours?

A. I believe it is common at all foundries in its general principle.

X Q. 37. Did you make any other articles besides car wheels?

A. We made occasionally some chilled rolls, small ones, and frogs for railroads; the bulk of the business was wheels.

X Q. 38. Supposing you had been making small articles, such as sash weights, with three cupolas, would you have used the large ladle in the manner you have described?

A. It would not be necessary to make sash weights out of uniform material; you can make them the cheapest way in the world.

167 X Q. 39. Would it not be necessary, however, or a great convenience, to have a large ladle to fill the smaller ladles?

A. In making sash weights and that kind?

X Q. 40. In making small articles.

A. Not necessarily.

X Q. 41. It would be no convenience, then?

A. Not at all. I might say in connection with that, if you wish it, we have another cupola, and always have had inside of that, for making small castings such as car boxes, etc., that we tap right into the ladle from which we pour the castings.

X Q. 42. In making small car wheels did you employ small ladles of a uniform size, or did you employ small ladles of different sizes?

A. All our minor wheels were made out of the same iron we poured the large wheels from, and the same kind of ladles.

X Q. 43. There was no cover to the large ladle, was there?

A. I think at one time we had a cover, but it was removed afterwards, as it was not found useful.

X Q. 44. In the cupolas you used, how much molten metal could you use in the bottom one?

A. We generally tapped out when it was about 500 or 600 pounds; it might possibly have held a little more.

X Q. 45. How much were your cupola furnaces supposed to hold, or could hold, do you know?

A. I don't know; I suppose they would hold 800 pounds; I never tried it.

Signature of the witness waived, by mutual consent of counsel.

168 *Testimony of Adam J. Frederick.*

ADAM J. FREDERICK, being duly sworn as a witness on behalf of the defendant, deposes and says in answer to interrogatories proposed to him by P. T. Dodge, counsel for defendant, as follows, to wit:

Q. 1. State your name, age, residence and occupation.

A. *Adam J. Frederick*: I live at 1629 South Broad street, Camden, Pa.; I am 71 years old, and a molder, employed at Whitney's car wheel works at Philadelphia.

Q. 2. How long have you been employed in the Whitney car wheel works?

A. Forty years.

Q. 3. Continuously?

A. I have been away three years, but it was forty years up to the time I went away, and now I am back again.

Q. 4. Examine the Defendant's Exhibit No. 1, and state, if you know, what it represents.

A. This model represents Whitney's car wheel works, as near as any man could make it. The cupola and the spouts and the ladle are all just like the Whitney car wheel works arrangements.

Q. 5. To your knowledge, how long has the plant like Exhibit No. 1 existed at the Whitney works?

A. The summer of 1857 it was put there.

The testimony of this witness in regard to the exhibit is objected to, for the reasons stated in preceding testimony.

Q. 6. Say whether or not the plant like the Exhibit 1 has continued in use in the Whitney works.

A. It has continued in use up to the present time; it is in use still.

Q. 7. Please state, for the information of the court, what the parts A, B, C and D in this exhibit represent.

169 A. A represents the furnaces; B represents the spouts that run from the three furnaces to the large ladle; C is the large ladle—that is, the reservoir that the iron is tapped into from A; D is the small ladle that we take out of the large one, and draw it up to wherever the mold is made, and pour it out into the mold.

Q. 8. Describe the practice in the Whitney works, from 1857 downward, as regards the handling of the metal; that is, what you did with it, where you started, and what became of it, etc.

A. The iron is charged into the large furnaces, and in those furnaces melted, and from that run into the reservoir or large ladle, and from the large ladle we empty it into the smaller ladles and then draw it up to the molds where they are, some very close by, and others way up at the end of the shop.

Q. 9. Please state what the practice was in 1857 downward, as to tapping the molten metal from the large furnaces, or cupolas, and how much molten metal was generally kept in the large ladle; that is, how often you tapped and when you tapped, and all about it?

A. We generally tapped into the large ladle until we got it very near full, and we kept it at that until we were done melting; we did that to regulate it with the number of ladles. When we found that the metal was going down, why we take off a ladle; when a little too much we put another one on. In that way we keep it as near one height as possible.

Q. 10. What was the object or advantage of using the large ladle?

A. To get a uniform temperature of the iron or to get a *uniform* iron.

Q. 11. Explain to the court why you got a more uniform iron by using the large ladle?

A. There is a great change in iron, and sometimes you may have an idea that you have the same kind of iron and put it into
170 a furnace, and it will be too soft or too hard without this large ladle. We find cupolas will change the iron by the blast; the bed of the coal that we put in first, if it should get down a little lower, a little below the melting point, it will harden up, and if it be up above the melting point too far it will soften. If we didn't have this large ladle why we would get some hard wheels. The ladle makes it uniform by the quantity of molten iron being put into that ladle, which works itself up, and you tap into this ladle and the iron running down into the spout into that ladle keeps it stirred up and makes it uniform.

Q. 12. Say whether or not the large ladle in the Whitney works receives and holds at one time metal from different cupolas?

A. It does. Sometimes we only run two furnaces, or whatever number we use they all run into the large ladle.

Q. 13. Am I correct in understanding from your testimony that molten metal runs from the different furnaces or cupolas into the large ladle, and that it is there mixed, as you have expressed it, while in a molten condition?

A. Yes.

Q. 14. Now, as a matter of fact, and as a result of thus drawing metal from the different cupolas, and mixing it in the large ladle as you have stated, did you succeed in getting a uniform quality of iron?

A. Yes; as a rule we take samples, and every ten ladles that are poured we take a sample, run it against a chill the same as a wheel, and then we break it. We have what we call the sample closet, and we put them in, and you could not tell which was the first or the last, not as a rule; the sample, you know, shows it is a uniform chill.

Q. 15. As the large ladle is employed at the Whitney works it is provided with some gearing by which it may be turned, is it not?

A. Yes, sir.

Q. 16. To pour the metal into the small ladle?

171 A. Yes.

Q. 17. In a general way, how long has such gearing been in use?

A. That same gearing has been in use ever since it started, since 1867; it is driven by power.

Q. 18. What is the capacity of the large ladle?

A. I think, when it is newly lined, it will hold between 15 and 16 tons.

Cross-examination without waiver of objection:

X Q. 19. How often do you tap from the cupolas into the large ladle?

A. It varies a little; some days it melts a good deal faster than it does others. We might average about 15 minutes.

X Q. 20. How long does it take to make the tap?

A. That I could not say exactly. I have never timed it; they generally tap it until they see that it is all out, but I have never timed it; not that.

X Q. 21. It is very important in making car wheels to get an even chill—that the metal be poured at an even heat—is it not?

A. Well, it used to be more so than it is now at the present day; those Whitney chills, since we have them in use, we can pour at white heat, and we got a good result every time—the contracting chill. When we had a plain chill we had to just have the metal as near as we could tell by the eye, at a certain heat.

X Q. 22. When were these contracting chills put in use?

A. They have been in use, I could not tell exactly how long. I think that the first we made was at the time of the Centennial; we had some of them out there. It is 12 or 14 years, as near as I can tell.

X Q. 23. When did you commence using them exclusively?

172 A. I could not say just how many years.

X Q. 24. About when did you begin casting without the use of the plain chills?

A. I could not tell, but I think it is ten years; perhaps more.

Signature of the witness waived by mutual consent of counsel.

Adjourned until 2.30 p. m.

Testimony of Harry H. Campbell.

2.20 P. M.

Met pursuant to adjournment.

HARRY H. CAMPBELL, being duly sworn as a witness on behalf of defendant, deposes and says, in answer to interrogatories proposed by P. T. Dodge, counsel for defendant, as follows, to wit:

Q. 1. State your name, age, residence and occupation.

A. Harry H. Campbell; age, thirty-six; residence, Steelton, Pennsylvania; I am superintendent of the Penna. Steel Company, at Steelton, Pa.

Q. 2. How long have you been connected with the Penna. Steel Company?

A. Since 1879.

Q. 3. What business is carried on by the Penna. Steel Co., at Steelton?

A. The manufacture of open-hearth and Bessemer steel.

Q. 4. Have you any knowledge of there being any use, in the Pennsylvania Steel Co., of a plant in which a ladle is used between the cupolas and the converter?

A. I have.

Q. 5. Please state if there is here present any model representing that plant, and if so, indicate the same.

173 A. There is one (pointing to model). This model here represents one-half the Bessemer plant. The other half is the same.

Model referred to by the witness is offered in evidence, and marked "Defendant's Exhibit No. 5, Model Penna. Steel Company Plant."

Objected to as incompetent and irrelevant.

Q. 6. When, if you know, was the plant of the Pennsylvania Company like Exhibit 5 put in operation?

A. In the fall of 1881.

Q. 7. How long did it run in the condition represented by the model Exhibit 5?

A. It has run, with only ordinary interruptions, up to very nearly the present time.

Q. 8. Referring to the model Exhibit 5, please state what the parts marked "A," "B," "C," "D," and "E," represent.

A. The parts marked A represent the cupolas for melting iron. The part marked B represents the runner leading from the cupolas to the receiving ladle; the part marked C represents the receiving ladle; the part marked D the runner from the receiving ladle to the converter, and the part marked E represents the converter.

Q. 9. Please state the operation of the Pennsylvania steel plant, as represented in Exhibit 5, with respect to the treatment of the metal and the use of the ladle C.

A. The iron is melted in the cupolas in the ordinary way. It is tapped whenever convenient, or whenever the cupola is full. There may be one cupola tapped at the time, there may be two or three or four. All the iron runs into the receiving ladle C. When convenient the iron is tapped from this receiving ladle down the spout D into the converter E. The time of this pouring depends upon the converter and whether it is ready for a charge. The amount

174 of iron in the receiving ladle C may be just sufficient for a charge or it may be enough for two charges, or it may be any amount between. It is the usual custom to have much more iron in the receiving ladle than is necessary for one charge, so that after a charge is poured down into the converter a considerable amount of metal, varying from 5,000 to 20,000 pounds, remains in the ladle. After pouring the charge for the converter it is customary to tap more iron into the receiving ladle before pouring the receiving charge into the converter.

Q. 10. What was the amount of metal usually tapped from the cupolas in the Pennsylvania works at a time?

A. It will vary in the case of one cupola, from 4,000 pounds to 14,000; usually about 8,000.

Q. 11. What was the capacity of the receiving ladle C?

A. From 35,000 pounds to 40,000 pounds, varying with the condition of the lining.

Q. 12. With what frequency was metal tapped from the cupolas into the receiving ladle?

A. At intervals of about ten to twenty minutes.

Q. 13. As a matter of fact, in practice at the Pennsylvania steel works, did the receiving ladle C receive or hold at the same time metal delivered from two cupolas or more?

A. It almost invariably held iron from two cupolas, if not always, and usually iron from more than two cupolas; almost always from more than two cupolas.

Q. 14. As a matter of fact, was there in the receiving ladle at the Pennsylvania works a mixture of iron received from different cupolas or different runs from the same cupola?

A. The iron in the receiving ladle would be almost always a mixture not only of iron from different cupolas, but of different runs from the same cupola, owing to the fact that a large body of iron was left over from every charge.

Q. 15. What effect, if any, did the receiving ladle C, as used in the Pennsylvania works, have on the uniformity in the composition of the metal passing to the converter?

175 A. It had the effect of securing considerable uniformity, owing to the fact that there was a mixture of the products of different cupolas, and even when the cupolas were working in unlike ways their product would be averaged in the receiving ladle.

Q. 16. Had the mixing ladle, as used by the Pennsylvania Steel Company, any advantage or effect as a reservoir or storage vessel between the cupola and the converter; if so, what was there?

Objected to as leading.

A. The receiving ladle was a reservoir, inasmuch as melting could be continued in the cupolas, although there should be some interruption in the converter department, since the iron could be tapped from the cupolas into the receiving ladle, waiting for the time when it could be used in the converter.

Q. 17. In the preceding answers you have described the action of the Pennsylvania plant as illustrated in the model, Exhibit 5. Please say whether or not that plant was operated in the manner and with the results you have stated during the interval between 1881 to the end of 1895?

A. It was operated in the manner I have described between the years 1881 and 1895. It was operated continuously, with the usual interruptions.

Q. 18. Please examine the drawing now handed you, and state, if you know, what it represents, and where it came from?

Drawing handed witness.

A. The drawing before me represents the No. 2 Bessemer plant of the Pennsylvania Steel Co., which is the plant described in my previous testimony, and the drawing is evidently taken from a tracing, which to my personal knowledge has been, and is, in the drafting room of the Pennsylvania Steel Company at Steel-
176 ton, Pa., the drawings having been made, I believe, when the Bessemer was built. I ihink the same drawing is now on file, and kept as a matter of record.

The drawing referred to by the witness is offered in evidence and marked "Defendant's Exhibit No. 6, drawing Penna. plant, 1881."

Q. 19. Please say whether or not the drawing, Exhibit 6, is a correct representation of the Penna. plant, regarding which you have testified, particularly as to the cupolas, spout, ladle and converter?

A. The drawing is a correct representation, to the best of my knowledge and belief, of the arrangement of cupolas, spouts, receiving ladle and converter, of the Bessemer plant of the Pennsylvania Steel Co.

Q. 20. Referring to the drawing, Exhibit No. 6, please state what the parts lettered A, B, C, D and E are?

A. A, A represents the cupolas, B represents the spout leading from the cupolas to the receiving ladle; C represents the receiving ladle; D represents the spout leading from the receiving ladle to the converter and E represents the converter.

Q. 21. What was the usual charge delivered from receiving ladle to the converter?

A. The usual charge from the receiving ladle to the converter varied from 14,000 to 17,000 pounds.

Cross-examination:

X Q. 22. Referring to the model, I ask you where the track shown there leads to?

A. That track is merely for the sake of changing ladles when the lining of the ladle is worn out. This only happens once in several days.

X Q. 23. Please describe the lining of the ladle, giving its thickness?

A. The lining of the ladle is partly brick, mostly loam
177 sand and varies in thickness, being about two inches at the top and perhaps seven or nine inches at the bottom, these figures being approximate and to the best of my knowledge and belief.

X Q. 24. Would this lining average five inches in thickness?

A. I could not state what the average would be.

X Q. 25. In the use of these cupolas was the pig metal sorted or tested before it was placed in the cupola?

A. It is sometimes sorted and it is sometimes analyzed. It is

sometimes both sorted and analized, and it is sometimes neither sorted nor analyzed.

X Q. 26. Under what circumstances do these differences exist?

A. These differences arise under variant conditions of practice, whether we are using irons of our own manufacture or whether we are using irons that are bought from outside, and whether we are in a hurry in using our own irons and have not time to make an analysis.

X Q. 27. Your general practice is to either sort or test the pig metal, is it not?

A. We so often use iron of our own manufacture without any analysis that I would not state that it is our general practice to so analyze. We never make any tests of the iron aside from the mechanical analysis unless the examination of the fracture of the iron be so considered.

X Q. 28. In your own iron do you not generally analyze the metal before it is put in the cupola?

A. On our own iron we always make an analysis, but, as stated before, when we are in a hurry we very often use the iron and have it converted into steel before the analysis has been reported.

X Q. 29. Do you ever recollect of seeing 35,000 pounds of molten metal in the ladle?

A. I distinctly recollect the weighing of considerably more than 35,000 pounds on several occasions, and am quite certain
178 that 35,000 pounds is a very common and usual amount to be held in the receiving ladle.

X Q. 30. How much does the ladle skull before it goes out of service?

A. Sometimes the ladle skulls considerably before it goes out of service, but usually a ladle is removed not because it skulls but because the lining gets thin, in which case the capacity is greater.

X Q. 31. What would be the effect of tapping the cupolas directly into the converter—that is, to make the ways continuous? What would the effect be on the iron?

A. It would be disadvantageous for more than one reason. First, considerable slag from the cupolas would reach the converters, which causes slopping and waste of metal; secondly, there would be no means of obtaining the uniformity which the receiving ladle insures, because a new cupola and an old cupola do not work the same. With us a new cupola almost always gives an iron of a very much higher temperature than a cupola which has been running for some time, and this iron requires a larger amount of scrap in a converter than the regular run of iron; and since it is difficult to estimate exactly how much more scrap would be required the result of using the iron directly from such new cupola would mean a lack of uniformity in the temperature of the steel, which is a matter of the most vital importance.

X Q. 32. Supposing you were using three cupolas and would tap a certain amount of metal directly from the cupolas, one-third from each, into the converter the way I have suggested, and then you should use the same number of cupolas and the same amount of

iron, using the intervening ladle, what would be the difference in the result of product?

A. It would be utterly impracticable, if not utterly impossible, to tap three cupolas at one time and be certain that the same amount of metal came from each one of those cupolas, or to be certain
179 within any reasonable limit how much the total weight from the three cupolas would be; and, even if these two difficulties could be surmounted, there would still be the cupola slag to contend with, which would create slopping and loss of metal from the converter.

X Q. 33. In the cupolas you have testified to at Steelton how long does it take to melt the charge up to the time when you commence to tap—that is, at the commencement of the process?

A. The operation of the cupolas in regular practice is continuous, and it is impossible to say how long it takes to melt the charge; but in a new cupola the first iron which is put in is melted in sufficient quantity to make a tap in about two hours.

X Q. 34. You have spoken of the weight of the metal in the ladle; is there not a weighing apparatus in the ladle?

A. The ladle sits upon a pair of scales, and the pair of scales rests upon a hydraulic lift, so that the ladle can be weighed with the iron contained in any position of the hydraulic lift.

X Q. 35. If the ladle were on a high plane so that it could pour down into the converter the lift would be unnecessary, would it not?

A. If the cupolas and the ladle both were raised a sufficient amount, the lift would be entirely unnecessary.

X Q. 36. Is not a receiving vessel standing on scales an ordinary device in steel plants?

A. I believe that such a receiving ladle is a common device in American steel plants, although I am not cognizant of the size of such ladles in other plants.

X Q. 37. Are you not aware that there are other plants where they do not entirely empty the ladle?

A. I do not remember the practice of other plants in that respect.

X Q. 38. How many blast furnaces have they at Steelton?
180 A. We have four blast furnaces.

X Q. 39. Did you manufacture any considerable quantity of your own pig iron?

A. We manufacture at the present time nearly all our Bessemer pig iron.

X Q. 40. Is there any cover to this ladle at the Steelton works?

A. There is no permanent cover, although it is the almost universal practice to cover the molten metal as soon as it is tapped with a layer of coke dust in order to prevent the loss of heat by radiation.

X Q. 41. This coke dust is applied at each tap, is it?

A. It is applied, as I have said, at almost every tap, if not every tap.

X Q. 42 About how much coke dust do you use?

A. There are a few shovelfuls thrown on at every tap, which, with

the coke dust remaining with the molten iron which is left in the ladle after tapping the charge, and with the cupola slag, of which there is always some in the ladle, forms a coating varying from quarter of an inch to one inch in thickness.

X Q. 43. Is it not true that by leaving a portion of molten iron in the ladle you can more certainly pour an exact, predetermined amount into the converter than if you poured out all the iron each time?

A. The difference would probably be in favor of leaving an amount of iron in the ladle, but there is no radical importance to be attached to this point on the score of accuracy in weight.

X Q. 44. What experience have you had at other steel plants besides those at Steelton?

A. I have never been employed at any other concern or corporation except the Pennsylvania Steel Company. I have visited several other plants, both in this country and abroad.

181 X Q. 45. Do you know what relation exists between the Pennsylvania Steel Company and the defendant in this suit?

Objected to as incompetent and immaterial.

A. I want to know what is meant by the word relation.

X Q. 46. Is there any relation between the two?

A. I don't understand.

Redirect examination by Mr. DODGE:

Q. 47. Is the use of the receiving ladle at the Pennsylvania works, does any material skulling or chilling of the metal occur?

A. Only in exceptional cases, when there is a long delay, or possibly when the iron happens to run cold, owing to lack of fuel in the cupolas.

Q. 48. Do you know of your own knowledge that there is any business connection or association between the two corporations, the Pennsylvania Steel Company and the Maryland Steel Co.?

A. Personally and strictly speaking, I do not know the exact relations between the Pennsylvania Steel Co. and the Maryland Steel Co., except from newspaper statements and hearsay.

Signature of witness waived by mutual consent of counsel.

182 *Testimony of Jacob B. Martin.*

JACOB B. MARTIN, being duly sworn as a witness on behalf of defendant, deposes and says in answer to interrogatories proposed by P. T. Dodge, counsel for defendant, as follows, to wit:

Q. 1. State your name, age, residence and occupation.

A. Jacob B. Martin, age 49 years. I am superintendent of the Bessemer department of the Bessemer steel works of Pennsylvania Steel Company, at Steelton, Pa. I am a resident of Steelton, Pa.

Q. 2. How long have you occupied that position?

A. The position that I hold now I have occupied for twelve

years. I have been with the Pennsylvania Steel Co. for 30 years, since 1866.

Q. 3. Please examine the model "Defendant's Exhibit No. 5," and state, if you know, what it represents.

A. A is the cupola, B is the runner that conveys the iron from the cupola to the receiving ladle or receiver reservoir C, and from the reservoir C it is raised upon the lift and poured down through the runner D and through the converter E. This is a model of the two cupolas and the runner, the receiving ladle and the receiving spout and converter, such as are used at the Pennsylvania steel works.

Q. 4. Please examine the "Drawing Exhibit 6," and say what that represents.

A. That represents a blue print of the drawing of the Pennsylvania steel works, of the Bessemer department, the same department that is represented in the model.

Q. 5. Please say whether or not Exhibits 5 and 6 fairly represent the Pennsylvania plant, as to the parts you have enumerated.

A. The drawing and model represent the plant that I have enumerated of the Bessemer department of the Pennsylvania steel works.

183 Q. 6. When was the plant of the Pennsylvania Steel Co. put into operation, as represented by Exhibits 5 and 6?

A. The Bessemer department of the Pennsylvania steel works was put in operation on the 12th day of September, 1891.

Q. 7. Between September, 1881, and the end of the year 1895, with what continuity was this Pennsylvania plant operated?

A. It was in operation from the 12th day of September, 1881, until the present time with once in a while a short stop to make needed repairs, but otherwise running continuously.

Q. 8. Please describe the operation of that plant so far as a melting of the metal and its delivery to the receiving ladle and thence to the converter are concerned?

A. The cupolas are lined with brick, then there is a bottom in the cupola that is put up with loam sand and then there are 3,000 or 4,000 pounds of coke or coal put into the bottom of the cupola and that is lit off and it takes five hours for that to turn up and after five hours we begin to charge the pig iron into it. We put 6,000 weight of pig iron into a charge and a layer of coke between every charge. We keep charging continuously. Then we put the wind or blast on the cupola, and two hours from the time we put the blast on we begin to tap the iron. We charge three and four of those cupolas and they are all charged the same way, just as that one. The iron is tapped out of the cupolas into a receiving ladle, and the receiving ladle holds from 35,000 to 40,000 weight of iron. When our converters are ready and hot enough, we pour 14,000 to 17,000 pounds down the runner D into the converter E. Then we tap again into the ladle and keep on tapping continuously from Monday morning, 5 o'clock, until Saturday afternoon at 3 o'clock. We invariably have from 5,000 to 20,000 of iron in the ladle when

we tap into it again from the cupolas. When we make re-
184 pairs of the converter, we keep on melting and tapping out into the ladle and reservoir, and when we have a needed repair made in the converter, we keep right along with the pouring. The ladle is lined with firebrick and a little loam over the top of the brick. The thickness of that lining in the bottom is from 4 to 7 inches, and on top of the ladle 2 inches. That ladle invariably cuts out and becomes larger. The reason that the ladle is taken off is on account of a cutting away in the bottom, along the rim. We generally run a ladle four days, when it is taken off and another put on. We have two tracks. The ladle sits on a truck and we can run that ladle off down to the other end and bring another ladle on. That is what the truck is used for.

Q. 9. State the principal advantages, if any, which attend the use of the receiving ladle between the cupolas and the converter, the ladle holding, as you have stated, an amount greatly in excess of the converter charge.

A. The cupolas hardly ever melt alike in temperature; the new cupola always melts hotter, the coke being heavier or lighter, or perhaps not distributed alike. Therefore the receiving ladle, with 5,000 or 20,000 iron in it, after pouring the heat into the converter, tends to mix the metal as the succeeding charge is tapped.

Q. 10. Please say whether or not the receiving ladle, as used in the Pennsylvania Steel Co., has been practical and successful in its operation.

A. The receiving ladle of the Pennsylvania Steel Co. has been practical in its operation.

Q. 11. Please say whether or not the steel produced in the Pennsylvania plant was of a satisfactory and uniform character.

A. I think the steel produced is of a uniform character.

185 Cross-examination:

X Q. 12. You have a similar ladle to the one you have testified to in connection with your spiegel cupolas, have you not?

A. We have a similar ladle in connection with our plant, only it is not near so large; it is a small ladle.

X Q. 13. It has a weighing attachment to it, has it not, this spiegel ladle?

A. Our spiegel ladle has a weighing attachment; it sits on a lift.

X Q. 14. And the ladle performs substantially the same function as the ladle shown in the model, does it not?

A. I don't think it does; it is not near so large, it only holds a charge of spiegel, and the other ladle is large, it holds almost three of our charges—17,000.

X Q. 15. Is it customary to empty the spiegel ladle of one charge?

A. It is customary to empty the spiegel ladle on a charge.

X Q. 16. Before charging the pig metal to the cupola, it is your custom to analyze the pig metal, is it not?

A. Well, we do; we analyze the pig metal, but very often we are obliged to use that pig iron before we get the analysis from our lab-ratory. We have gone two or three days without any analysis from the lab-ratory.

X Q. 17. That is only because you are in a hurry, is it not?

A. Well, no; our furnaces run very regular; we do not seem to have any trouble.

X Q. 18. Do you consider it good modern practice to have pig iron converted and rolled into the finished rails before the analyses of it are reported to the management of the converting department?

Question objected to as calling for an expert opinion wholly foreign to any question involved in this cause, and the witness is instructed he may answer or not, as he sees fit.

186 Counsel for complainant refuses to further cross-examine the witness and will move to have his testimony stricken from the record.

Signature of the witness waived by mutual consent of counsel.

Adjourned to 10 o'clock on January 10th, Friday.

FRIDAY, *January 10th*—10 o'clock a. m.

Met pursuant to adjournment.

Appearances as before.

Testimony of Homer A. McGarthy.

HOMER A. MCGARTHY, being duly sworn as a witness on behalf of the defendant, deposes and says, in answer to interrogatories proposed by P. T. Dodge, counsel for defendant, as follows, to wit:

Q. 1. State your name, age, residence and occupation?

A. Homer A. McGarthy; 50 years old; foreman of the Cambria Bessemer steel works; residence, at Johnstown, Penna.

Q. 2. Please state where the Cambria works are located, and, in a general way, the character and extent of the business?

A. They are located at Johnstown, Pa. The character of the works is the production of Bessemer and open-hearth steel. After the steel is made, it is manufactured into rolls and angles. What is called the Gautier department, that still belongs to the Cambria, all the one company. I suppose there are 6,000 or 7,000 men employed by the Cambria.

Q. 3. How long have you been connected with the steel department of the Cambria works?

A. Twenty-four years.

Q. 4. Please say whether you see present any model which represents the Cambria plant as regards the arrangement of cupolas, converters and intermediate parts.

187 A. Yes, sir; I recognize this as the Cambria plant.

The model referred to by the witness is offered in evidence and marked "Defendant's Exhibit No. 7, model Cambria plant."

Q. 5. Please state, referring to Exhibit 7, what the parts lettered A, B, C, D and E represent?

A. A represents iron cupolas, B a spout, C represents the ladle, D is the runner, and E is the converter.

Q. 6. Please describe, in your own way, the operation of the Cambria plant, represented by Exhibit 7, as regards the melting of the metal and its delivery to the converter.

A. In starting the works, first we have to get up steam. We use, generally speaking, hydraulic pressure in the working of all frames and hoists; when that is ready we start to fill our cupolas, light them, and in from five to eight hours they are ready to be charged with pig iron. They are then charged, with blast put on, and in the course of two hours we are ready to tap. We then tap out sufficient in ladle C to make a heat; more, usually speaking. Then we pour the iron into the runner that leads to the converter. Then the blast is turned on the converter, and the hydraulic pressure comes after that, and the converter is straightened up. The charge is then blown until it is rid of all impurities, and then the converter is turned on a side. She is then ready to receive the carbonizer. From there it is poured into the ladle, transferred over the moulds and cast into ingots.

Q. —. What is the practice at Cambria as to tapping molten metal into the ladle C? Is the ladle filled from one or more cupolas?

A. From two to six cupolas. We use down as low as two cupolas and as high as six at one time We aim to tap all at the same time, and the metal from the different cupolas runs into one ladle.

Q. 8. After this ladle has received the metal from two or more cupolas you pour out of the mixed metal to the converter.

188 A. Yes, sir; a portion of it—sufficient of it to make a charge.

Q. 9. What is the capacity of the intermediate ladle C with reference to a converter charge? Does it hold more or less than a converter charge?

Objected to as leading.

A. Our ladle holds about 7,000 pounds more than a converter charge. The capacity of the ladle is from 32,000 to 35,000 pounds. The converter charge is from 26,000 to 28,000 pounds.

Q. 10. What has been the general practice at Cambria as to filling the intermediate ladle or keeping it filled?

A. The general practice is, when tapping, to fill it full before pouring out.

Q. 11. And after you have poured out a portion from the ladle, for a converter charge, what was the practice as to again filling the ladle?

A. The ladle was taken back to the cupola spout and tapped right in on what was left in the ladle and filled up again.

Q. 12. If I understand you, then, the practice at Cambria was to tap the molten metal from two or more cupolas into the receiving ladle; then to pour from this ladle a portion of this metal for a con-

verter charge, and thereafter to again draw into the ladle, in addition to the molten metal remaining in it, metal from one or more cupolas, thus filling the ladle again before charging the next converter; is that a correct statement?

A. Yes, sir, that is correct.

Q. 13. How long had it been the practice at Cambria to use an intermediate ladle in this manner?

A. For over 24 years.

Q. 14. During that period have you changed the capacity of the ladle or the charges of the converters, and, if so, when, and to what extent?

189 A. The first ladle of 1871 contained 21,000 pounds, and our converter charges were 12,500 pounds. In 1877 we increased our capacity to 28,000 in the ladle, charges at the converter at 15,500. In 1889 we increased the capacity of the ladle to 32,000 to 35,000, charges at converter 26,000 to 28,000.

Q. 15. Say whether or not the ladle in its different sizes, was used in the same manner and with the same effect or not?

A. As the sizes of the ladle increased the practice was the same. We fill our ladle up before taking the charge for the converter.

Q. 16. State the reason for or advantage of using between the cupola and the converter, the ladle holding more than a converter charge.

A. The plant would have to be changed to run so close. It would not be practical to work so close as just to tap the exact amount. The surplus iron gives us something to go on in weighing our charges, we are not cut down to a point. Sometimes heats are larger, sometimes smaller. It is strictly necessary to have a surplus back in your ladle under the present system of working.

Q. 17. Does any advantage attend the delivery of metal from two or more cupolas into the ladle at one time?

A. I think there is an advantage. Taking iron from the three cupolas would be much better than to take it from one because you will get a more uniform mixture.

Q. 18. Examine the drawings now handed you, and state, if you know, what they represent and where they came from.

A. This is a drawing of the Cambria Bessemer steel works that existed — 1879 and 1880, or along there.

Q. 19. Do you recognize these drawings?

A. Yes, sir; they came from the Cambria Iron Co.'s offices.

190 I recognize the ladle, the converter and all the other parts. The converter stacks were changed in 1880 or 1881 from the original Bessemer, and the ladle was enlarged at that time. That plant belonged to the second change, where we increased the size of our plant and put more of them up, five or six cupolas. Originally this receiving ladle stood on a stationary platform, but when this change was made the ladle was set on a lip to raise it up.

Drawing referred to by the witness is offered in evidence, and marked "Defendant's Exhibit No. 8, Cambria plant."

Q. 20. Please say whether or not the drawing, "Exhibit 8," illus-

trates the same Cambria plant as that referred to in your previous testimony.

A. Yes, it does.

Q. 21. Referring to drawings "Exhibit 8," please state what the parts lettered A, B, C and E are.

A. A represents the iron cupolas, B represents the runners that convey the iron to the ladle, C represents the iron ladle, and E represents the converter. The runner from the ladle to the converter is not here shown.

Q. 22. Examine the drawing now shown you, and state what it represents.

A. It is a plan view of the Cambria works in 1880 and 1881, and along there. A represents the cupola, B cupola runners, C cupola ladle, D is the runner that conveys the iron from the cupola ladle to the converter E; E is the converter.

The drawing referred to by the witness is offered in evidence and marked "Defendant's Exhibit No. 9, Cambria plant, 1880 to 1881."

Q. 23. State, if you know, where this drawing Exhibit 9 came from and when or where the original was made.

A. This is a drawing of the Cambria steel works. It was made at the Cambria office.

Q. 24. Do you remember ever seeing this drawing before?

191 A. I don't remember; I cannot say positively if I have ever seen it before.

Q. 25. Are you able to say whether or not this drawing Exhibit 9 faithfully represents the Cambria plant as it was about 1880 or 1881?

A. Yes, sir; it does represent the Cambria works at that time.

Q. 26. Please say with what continuity the Cambria plant, with the intermediate ladles, has been operated since it was started?

A. It has been the regular practice ever since the Bessemer was started to have intermediate ladles between cupola and converter; the works have been running from one year to another continuously.

Q. 27. At the Cambria works what was the usual amount of metal tapped from a cupola, and with what frequency did this tapping occur?

A. Ten to twelve minutes; if we are running in good shape every 10 to 12 minutes we tap a cupola. The amount tapped would be from 4,000 to 8,000 out of a cupola; of course it is sometimes more.

Cross-examination:

X Q. 28. You have seen a number of other steel plants besides the Cambria, have you not?

A. Yes, sir.

X Q. 29. Have you ever seen a Bessemer plant where they did not have an intermediate ladle in connection with the weighing scales such as you have described?

A. I never did.

X Q. 30. How many blast furnaces have they at the Cambria works?

A. Six at the works.

X Q. 31. How many converters?

A. Four.

192 X Q. 32. Do you know whether they ever used the direct process at the Cambria works?

A. They have lately.

X Q. 33. Did they ever experiment on it some years ago?

A. No, sir.

X Q. 34. They are now using the direct process in connection with a mixer, are they not? That is a receptacle for receiving the molten metal from the blast furnaces and drawing from this mixer to a ladle, by which the metal is conveyed to the converters?

A. We are now using that, yes.

X Q. 35. This mixer was put in by a contract with Mr. Aiken, was it not?

Objected to as incompetent and immaterial.

A. I am not positive about it, but I think I understood so; but I could not be positive on that.

Further objection is made that the witness has no personal knowledge on the subject in question.

X Q. 36. When was this mixer built?

Same objection continues.

A. The summer of 1889.

Redirect examination by Mr. DODGE:

Q. 37. In the other steel plants where a ladle was used do you know whether it was of the same capacity in relation to converter charges as the Cambria ladle?

A. I could not say in regard to that.

Recross-examination:

X Q. 38. In the use of the ladles at other plants, is it not customary always to put a somewhat larger amount of metal
193 in the ladle than is necessary for the charge of the converter, so as to enable them to weigh out the amount required for the converter?

A. Yes, sir.

Signature of the witness waived by mutual consent of counsel.

Testimony of F. P. Hershey.

F. P. HERSHEY, being duly sworn as a witness on behalf of defendant, deposes and says, in answer to interrogatories proposed by P. T. Dodge, counsel for defendant, as follows, to wit:

Q. 1. State your name, age, residence, and occupation.

A. F. P. Hershey, age, 43; residence, Johnstown, Pa.; occupation, cupola hand at Cambria Iron Co., Johnstown, Pa.

Q. 2. How long have you been connected with the Cambria Iron Co.?

A. About 20 years.

Q. 3. Please examine the model Defendant's Exhibit No. 7, and state, if you know, what it represents.

A. It is the plant of the Cambria Iron Co.'s steel works at Johnstown.

Q. 4. At what time was the Cambria plant arranged as represented in Exhibit No. 7?

A. About 1879 or 1880 I think it was in this shape, and continued so, I suppose, about five or six years, as near as I can tell.

Q. 5. Referring to Exhibit 7, state what is represented by the parts letters A, B, C, D and E.

A. A represents the cupolas, B represents the runner conveying the iron from the cupolas to the receiving ladle C, C represents the receiving ladle, and D represents the runner conveying the iron from the receiving ladle into the converter. E represents the converter.

Q. 6. State in as few words as you can, what the practice
194 was at the Cambria works in 1880 or 1881 and the succeeding years as to handling the metal in this plant up to the time it reached the converter.

A. In the first place, the cupolas were lit up, and then after they were lit about from 5 to 8 hours we started to charge them with pig metal, and after they were charged we put the blast on the cupolas, and in about two hours we would start tapping the iron from the cupolas. We then tapped the iron into the receiving ladle C until we got it full, and then we would pour out into the converter sufficient to make a charge. Then we would start filling the ladle up again. As the converters were ready to receive another charge we would have our ladle full and pour another charge into the converter, and so on.

Q. 7. What was the capacity of that receiving ladle C in 1880 or therebouts?

A. Twenty-eight thousand pounds.

Q. 8. About how many taps from the cupolas would that receiving ladle hold at one time?

A. We can tap from two to six cupolas in the ladle at one time. She would hold the taps from six cupolas at one time.

Q. 9. After having the receiving ladle filled with 28,000 pounds of molten metal, how much did you pour out at a time for a converting charge?

A. We poured out from 15,000 to 21,000.

Q. 10. So that you would leave in the ladle, after pouring, from 7,000 to 13,000 pounds of molten metal?

A. Yes, sir.

Q. 11. And into this molten metal which was left in the ladle you would pour additional molten metal from one, two or more cupolas, until the ladle was again filled?

A. Yes, sir.

Last question objected to as leading.

Q. 12. During your service for the Cambria Company was the capacity of the intermediate ladle changed?

195 A. Yes, sir; the ladle was changed from 28,000 to from 32,000 to 35,000 about, as near as I can say, seven years ago.

Q. 13. Before the ladle was of 28,000 pounds capacity, was it used in any other size?

A. Yes.

Q. 14. When was that, and for how long?

A. That was when the works were first started, which was, I think, in 1871; I am not positive. The ladle then had a capacity of 21,000, and the converter charges were 12,000.

Q. 15. With your ladle holding 31,000 to 32,000, as now used, what was the converter charge?

A. From 26,000 to 28,000 pounds.

Q. 16. Now, during the use of these ladles, commencing with 21,000 pounds and then increased to 28,000, and afterwards increased to 32,000 or more, did you change the practice or operation in handling the metal?

A. Yes; the first ladle stood stationary and the next ladle stood on a lift, a hydraulic lift, as represented in the model Exhibit 7; the next ladle stood on a car, and that car is on a track; it is hauled by a cable rope from one vessel to the other.

Q. 17. In using these successive ladles of different sizes did you continue to draw the metal from different cupolas into the ladle and then empty a part of this metal to the converter, and then refill the ladles again before charging the next converter, as you have described?

Objected to as leading.

A. Yes, sir; we still continued to fill the ladles up with all three sizes.

Q. 18. Please examine the drawings Exhibits 8 and 9, and state, if you know, what they represent?

A. Those are drawings of the cupolas of the Cambria plant as it existed, I think, in about 1875.

196 Q. 19. Calling your attention to the arrangement of the cupolas, ladle, lift, etc., state, if you can, any more closely, when the plant was in that shape?

A. I think it was changed about 1877.

Q. 20. Did you ever have occasion to examine these particular drawings before?

A. No, sir.

Cross-examination:

X Q. 21. Could you have poured two heats for the converter without refilling the ladle?

A. No, sir.

X Q. 22. Where the ladle was pulled by a cable, did you use scales for weighing the metal in the ladle?

A. Yes, sir.

X Q. 23. The use of these scales is necessary, is it not?
A. Yes, sir.
X Q. 24. Was there a scale for each converter?
A. Yes, sir.

Testimony of T. G. Wolf.

T. G. WOLF, being duly sworn as a witness on behalf of the defendant, deposes and says in answer to interrogatories proposed by P. T. Dodge, counsel for defendant, as follows, to wit:

Q. 1. State your name, age, residence and occupation.
A. T. G. Wolf; residence, Scranton, Pa. I am superintendent of the North mills, Lackawanna Iron and Steel Co.; age, 52 years.
Q. 2. State in a general way the business of that company and its extent.
A. We are manufacturers of steel and iron; we use the Bessemer process only in the manufacture of steel. We are also manufacturers of coal. It is a large corporation, and we employ about 5,000 men in all.
197 Q. 3. How long have you been connected with the Lackawanna Company?
A. About 34 years.
Q. 4. Please say whether or not the Lackawanna Co., has a plant in which a ladle is between cupolas and converters?
A. Yes, sir; this model represents the plant as it existed from 1875 to the latter part of 1889; this is only a half section of the plant as it existed at that time. It had two more cupolas and another converter.

Model referred to by the witness is offered in evidence and marked "Defendant's Exhibit No. 10, model Lackawanna plant, 1876."

Q. 6. State what the parts lettered A to E in this exhibit represent.
A. Letter A represents the cupolas; B represents the runners leading to a receiver or iron ladle; C the iron ladle; D the runners leading to the converter E.
Q. 7. Please state the operation of the Lackawanna plant, as represented by Exhibit 10, from 1876 downward.
A. Iron was charged in the cupolas and tapped from there into the ladle or receiver C, there weighed and the desired quantity run into the receiver.
Q. 8. What was the practice as to drawing metal from more than one cupola into the ladle at one time?
A. The usual practice was to tap the iron as soon as it was ready from one or more cupolas, at times all of them, until the ladle was filled.
Q. 9. Then, if I understand you, in the Lackawanna works the receiving ladle C contained at one time metal from two, three or more of the cupolas?

A. Yes, sir; I might say as a rule it contained metal from all of of them; it depends altogether upon the condition of the cupolas.

Q. 10. What was the capacity of the receiving ladle?

198 A. When newly lined it contained or held, or was estimated to hold 20,000 pounds; but as the lining wore it ran higher than that, 24,000 or 25,000. As the drawing shows, I think we carried a much thinner lining than was contemplated when the drawing was made, and so were carried more than 25,000 as a rule.

Q. 11. What was the customary amount taken from the ladle as a converter charge?

A. From 14,200 to 15,600 pounds, approximately.

Q. 12. After pouring a portion of the contents from the receiving ladle for the converter, what was the practice as to again filling the ladle?

A. The ladle was turned back into position, and the cupolas tapped again and filled ready for the next operation of the converter.

Q. 13. Then, if I understand you, in the ordinary course of operations, the ladle would at all times contain a quantity of molten metal?

A. I could not say at all times, but nearly all times; it was so intended; sometimes, you know, your converter will run a little faster than the cupolas will supply the iron but as a rule that was the practice.

Q. 14. Am I right in understanding from your testimony that this intermediate ladle served as an accumulator or reservoir to receive the molten metal from several cupolas and hold it until a portion was to be drawn off as a converter charge?

Objected to as leading.

A. Yes, sir.

Q. 15. What were some of the advantages attending the use of this intermediate ladle?

A. In the first place it would lead to a more thorough mixing of the metal, and next as a receiver to furnish a supply for the converters.

199 Q. 16. Please examine the drawing now handed you, and state, if you know, what it represents and when and for what purpose it was made?

A. From this drawing the Lackawanna plant was constructed; it is a print from the original drawing.

Drawing referred to is offered in evidence and marked "Defendant's Exhibit No. 11."

Q. 17. Referring to the drawing Exhibit 11, please say what the parts A to E, inclusive, represent?

A. A represents the cupolas; B is the runner from the cupola to the ladle; C is the receiving ladle; D the runner to the converter, and E the converter.

Q. 18. Are you familiar with foundry practice?

A. Yes.

Q. 19. What is the practice with respect to accumulation of molten metal from different furnaces or different taps from the same furnace in the receiver or reservoir; give any illustration you please?

Objected to as incompetent and irrelevant.

A. In our own foundry at the Lackawanna Iron and Coal Company's, we tap into a receiving ladle in making nearly all the small hand castings; that is, castings made from small ladles of iron; it is poured from the large ladle into the small ladle.

Q. 20. How long has this been the practice at Lackawanna?

A. I guess it commenced before my day; I have known of it 30 years.

Q. 21. Will you give the court an idea of the size of that receiving or accumulating vessel which you have used in your foundry?

A. I should say that ladle would hold probably three or four tons. It is tapped from the cupolas directly into the ladle, some time from two cupolas, but ordinarily from one. In making the large
200 castings where cupola iron is used as auxiliary, it is cast sometimes from two cupolas; we do not, as a practice, run two cupolas. We run successive taps from one cupola into the same ladle. The foundry practice with us is different from the cupola practice, in that we very rarely slag off.

Q. 22. If I understand you, then, it is your foundry practice to tap off the iron in small quantities into the large ladle, where it is accumulated, and from which it is drawn into small ladles as required at the foundry practice?

A. Yes, sir.

Q. 23. Then, in your foundry practice, as it has existed for thirty years, it has been the custom to accumulate different taps of molten metal in a reservoir or ladle where they were mixed together, so that the metal drawn from this ladle was an average product; is that true?

Objected to as leading.

A. Yes, sir; it was.

Q. 24. In your foundry practice was this operation of tapping the successive charges into the receiving or accumulating or holding ladle, and then drawing smaller portions out of this ladle from time to time, a continuing practice through the day?

A. During the pouring and the casting we would probably be only for a couple of hours during the day.

Q. 25. Is it, or is it not the fact that several times the capacity of the ladle was passed through it in the course of a day, without emptying it?

A. Yes, sir; it is a fact.

Cross-examination:

X Q. 26. It would be impracticable to tap the exact amount for the converters, without the use of the ladle, and the scales would it not?

A. Yes, it would.

X Q. 27. This is the reason for using an intermediate ladle with weighing scales, is it not?

201 A. No, sir; not altogether.

X Q. 28. It is a reason, however, is it not?

A. Probably that is one reason.

X Q. 29. When did you first recognize the mixing feature that you have spoken of in connection with the ladle?

A. I don't know; that has always been recognized.

X Q. 30. You are sure that the ladle at the Lackawanna Iron and Steel Company's works was large enough to pour two ladles for the converters without filling the ladle?

A. No, sir; unless you take the minimum heats of five tons then it will hold two ladles.

X Q. 31. It is necessary, is it not, in practical working, to have the ladle of somewhat larger capacity than the charge for the converters?

A. Why, no; it would not be absolutely necessary for that reason; that is, if the ladle were placed as ours was, on a scale, it could be done. It would be practical; yes, sir.

X Q. 32. Would not the mixing feature you speak of be much more complete if the ladle were large enough to hold several charges for the converters?

A. I suppose it would; yes, sir.

X Q. 33. If you recognized the advantageous feature in the mixing of the metal, why did you then not make your ladle large enough to hold several charges?

A. Our plant was constructed after the old Holly plant generally. At that time I was not familiar with the business and could not say.

X Q. 34. What does your present ladle hold?

A. I should say it holds the same as the one originally in.

X Q. 35. How much does your present converter hold?

A. We are drawing the same heats as originally.

X Q. 36. In your foundry the small ladles hold a less amount than the amount of a tap, do they not; I refer to the small

202 ladles into which the metal is drawn from the intermediate ladle?

A. No; because they are frequently tapped from the cupola directly into the small ladle. Anybody familiar with foundry practice knows that there would be some metal would flow off before the cupolas were melting rapidly.

X Q. 37. In making all classes of castings at your foundry do they always employ the receiving ladle?

A. No; we have an open-hearth furnace that we pour directly into the rail flask in casting rolls and pinions.

X Q. 38. In casting a moderate-sized casting it is perfectly possible to cast, tapping directly from the cupola into the casting ladle, is it not?

A. Yes, sir.

X Q. 39. What kinds of castings do you make at your foundry?

A. General castings, mill castings principally, for repairs and work about the works.

X Q. 40. Where you are making a large number of small castings, it is much more convenient to use the receiving ladle, is it not?

A. I presume it is; yes, sir.

X Q. 41. Have you ever used the direct process in your converter plant?

A. We have not.

Redirect examination:

Q. 42. You have been asked if an increase in the size of the ladle would increase the perfection of the mixing, to which you replied yes. Is this difference a difference in kind or a difference in degree?

Objected to as leading.

Question withdrawn.

Q. 43. When you increase the size of a ladle to increase
203 the perfection of the mixing, does it change the method of mixing or is it the carrying out of the same method in a more perfect manner?

Objection continued.

A. I don't think it would change the method of mixing at all. Only that you would get a larger quantity of metal; that is all.

Q. 44. But the mixing in either case, whether the ladle is large or small, would be of the same character?

A. Yes, sir.

Objection continued.

Signature of the witness waived by mutual consent of counsel.

Testimony of George F. Barnard.

GEORGE F. BARNARD, being duly sworn as a witness on behalf of the defendant, deposes and says, in answer to interrogatories proposed by P. T. Dodge, counsel for defendant, as follows, to wit:

Q. 1. Please state your name, age, residence and occupation.

A. George F. Barnard; age, 40 years; residence, Scranton, Pa.; I am superintendent of the North Bessemer mills of the Lackawanna Iron and Steel Co.

Q. 2. How long have you been so engaged?

A. I have been engaged as superintendent since the 1st of September, 1887.

Q. 3. Previous to that, were you connected with the works and familiar with the Bessemer process?

A. Yes, sir.

Q. 4. How long, in a general way?

A. I have been in the Bessemer department since the 21st of March, 1879.

Q. 5. Are you familiar with the Bessemer plant as it existed at the Lackawanna works in 1879?

204 A. Yes, sir.

Q. 6. Please examine the model Exhibit 10, and state, if you know, what it represents.

A. It represents the north mill of the Lackawanna Iron and Steel Co. or the converting department of the Lackawanna Iron Co., as it was.

Q. 7. Will you describe the parts as they existed in the Lackawanna plant, and as represented in Exhibit No. 10?

A. A represents the iron cupolas; B represents the runners to convey the iron from the cupolas to the receiving ladle C; C is the the receiving ladle; D represents the runners to convey the iron from the receiving or accumulating ladle to the converter; E represents the converter.

Q. 8. What was the practice at Lackawanna in 1879 and later as to filling the accumulating ladle, and as to delivering the metal thence to the converter?

A. The cupolas were charged with pig iron melted, and in the melted state run into the receiving or accumulating ladle. After filing the receiving ladle, the heat was run into the converter or vessel.

Q. 9. Will you state the frequency and amount of the taps from the cupola into the receiving ladle and capacity of the latter?

A. The iron was tapped from the cupolas into the receiving ladle whenever sufficient amount of iron was melted in the cupolas to fill the ladle, amounting from each cupola, varying from 6,000 to 8,000 pounds from each cupola.

Q. 10. And the ladle held what amount?

A. The ladle was estimated to hold 20,000; it has held as much as 25,000 pounds, depending upon the thickness or condition of the lining of the ladle.

Q. 11. If I understand correctly, this ladle C, when filled, at the Lackawanna works, contained three or more taps from the different cupolas?

Objected to a leading.

205 A. Yes, sir.

Q. 12. It would appear from your testimony that the mass of molten metal filling the ladle was a mixture of metal formed of the several taps from the cupolas—is that correct?

A. Yes, sir.

Objection continued.

Q. 13. After the accumulating ladle was filled by the several taps, what portion of the metal was delivered to the converter?

A. From five to seven tons would run out of the ladle to make a heat for the converter, or put it in pounds, I should say from 11,000 to 16,000 pounds.

Q. 14. In your Lackawanna practice say whether or not the ac-

cumulating ladle contained at all times a considerable quantity of molten metal?

A. Yes, sir; as a rule there was always molten metal in the ladle.

Q. 15. And to this residue of molten metal in the ladle you added from time to time, if I understand you from your testimony, additional molten metal tapped from the cupolas?

A. Yes, sir.

Q. 16. How long had this practice of filling the ladle with mixed metal, discharging a portion of this metal to the converter and then refilling the ladle by additional taps, continued?

A. Until the latter part of 1889; that is, the ladle as exhibited here by the model.

Q. 17. What change, if any, took place in 1889?

A. A third converter was added to the plant, making it necessary to transfer the ladle to two different points to enable us to run the heat into each of the three converters, and at that time the ladle was transferred from a stationary platform to a car to convey it.

206 Q. 18. But so far as the ladle itself and its use for accumulating and delivering metal were concerned, was there any material change?

The use of the word accumulating objected to as incompetent and improper, for the reason that witness has not testified to the use of the ladle as an accumulator, nor does the model show that the ladle is adapted to such use.

A. No, sir.

Q. 19. Does the use of that ladle, as mounted on the movable truck, still continue?

A. Yes, sir.

Q. 20. As a matter of fact, was and is the ladle, as used at Lackawanna, adapted for accumulating taps or charges from several different sources?

Objected to as leading, and also objected to as the word accumulating is indefinite.

A. It was adapted as an accumulator of molten metal from several different cupolas.

Q. 21. As a matter of fact, how was this Lackawanna ladle filled at one time, by one charge or by small charges?

A. The ladle was filled by tapping from two or more cupolas at the same time, or when not sufficient was received in that way, by tapping once or oftener from the cupolas.

Q. 22. Please examine the drawing "Exhibit 11," and state, if you know, what it represents.

A. It represents part of the cupolas, runners and ladle system of the converting department of the Lackawanna Iron and Steel Co., as it existed previous to 1890. A represents the iron cupola for melting pig iron; B represents the runners to convey the pig-iron cupola to the ladle C; C represents the accumulating or receiving

ladle for the melted iron from the cupola; D represents runner from receiver to converter; E represents the converter.

207 Q. 23. Is this drawing "Exhibit 11" a fair representation of the arrangement and proportion of the parts at the Lackawanna plant?

A. Yes, sir, it is.

Cross-examination:

X Q. 24. Referring to the drawings you have just spoken of, do you know when these blue prints were made?

A. No, sir.

X Q. 25. Do you know whether there has been any change made in the original drawings from which the blue prints were made since the original drawings were first made?

A. No, sir.

Drawings objected to as incompetent.

X Q. 26. Do you know when the word "receiver" was marked on that drawing?

A. I do not.

X Q. 27. Do you know whether, in the detail drawings, the ladle is marked "receiver"? I refer to the detail drawings of the receiver.

Objected to as not appearing that any such drawings as named existed.

A. I have not seen any detail drawings.

All drawings that have been offered in evidence relative to the plant of the Lackawanna Steel Co. objected to as incompetent, there being no proof to show when the blue print was made, or that it is a correct representation of the original drawing.

X Q. 28. It was a matter of indifference to you, was it, how much metal was left in the ladle after charging the converter, so long as there was enough metal left in the ladle to insure proper weighing?

A. Yes, sir.

X Q. 29. While you were blowing a heat you were, as a rule, tapping enough metal to make another charge for the converter, were you not?

208 A. We always tapped enough metal to fill the ladle, when possible.

X Q. 30. But is it not a fact that while you were blowing the heat you were tapping enough metal to make another charge?

A. Not necessarily; we tapped the metal to fill the ladle when a sufficient quantity was left in the cupolas to accomplish that.

X Q. 31. Did you not tap the metal from the cupolas before it was necessary to charge the converter?

A. We tapped the metal from the cupolas when the iron was what we call up in the cupolas.

X Q. 32. After charging the converter was there enough metal left in the ladle for a second charge?

A. There might have been, yes, sir; depending upon the weight of the heat that we were charging in the converter.

X Q. 33. Then that was your rule, to keep two or more charges for the converter in the ladle; is that correct?

A. It was our rule to fill the ladle. Sometimes the heats were sufficiently heavy so that the ladle would not hold two charges.

Question repeated.

A. No, sir; it is not the rule.

X Q. 34. As a rule the ladle did not contain two full charges for the converter?

A. They did not.

X Q. 35. As a rule, is a single tap from one of the cupolas sufficient for the converter?

A. No, sir.

X Q. 36. It never is, is it; that is, counting a full charge for the converter?

A. A single tap would not make a charge for a converter.

209 Redirect examination:

Q. 37. What did you mean by saying that it was a matter of indifference as to the quantity of metal left in the ladle after pouring a converter charge?

A. Why, after pouring a converter charge, there might be 5,000 or 8,000 of metal left in the ladle, and it is a matter of indifference whether it was a little larger or smaller quantity.

Signature of the witness waived by mutual consent of counsel.

Adjourned subject to agreement of counsel.

210 Circuit Court of the United States, District of Maryland.

CARNEGIE STEEL COMPANY, LTD.,
vs.
MARYLAND STEEL COMPANY OF BALTIMORE County and Frederick W. Wood, Receiver.
} In Equity. Patent No. 404,414.

Testimony taken on the part of the defendant under agreement of counsel, at No. 208 South Fourth street, Philadelphia, Pa., beginning this 25th day of April, 1896.

Present: J. K. Bakewell and Wm. Bakewell, on behalf of complainant; P. T. Dodge and R. F. Rogers, on behalf of respondent.

Testimony of J. W. Cabot.

J. W. CABOT, witness on behalf of defendant, being first duly sworn, deposes and says in answers to interrogatories proposed to him as follows, to wit:

Q. 1. State your name, age, residence and occupation.

A. J. W. Cabot; residence, Johnstown, Pa.; occupation, iron works superintendent.

Q. 2. State briefly what experience you have had in the iron manufacture.

A. During six years superintendent of steel works and rolling mill of the Bellaire Steel Company, Bellaire, Ohio; for about seven years in the employ of the Cambria Iron Company, first assistant superintendent of Bessemer, in charge of open-hearth department, assistant superintendent blast furnaces, and part of time as
211 chemist; also, was superintendent of the Bessemer works of the Maryland Steel Company, at Sparrows Point, for about a year.

Q. 3. During what years were you connected with the Maryland Steel Company?

A. From May, 1893, to April, 1894.

Q. 4. Say whether or not, during your service, the Maryland Steel Company employed a vessel to contain molten metal, which was taken thence to the converters?

A. Yes, sir; it did.

Q. 5. What was the shape, and what the capacity of that vessel?

A. There were two such vessels used; they were in general of a semi-cylindrical shape; patterned closely after the form of the tilting steel metal furnaces in use at Steelton, Pa. The capacity of each of these vessels was about 100 tons of liquid metal.

Q. 6. What was the principal purpose or function of the semi-cylindrical vessels used at Sparrows Point?

A. They were used as reservoir receptacles for receiving the casts of molten iron directly from the blast furnaces.

Q. 7. Did the vessels receive metal only from the blast furnaces?

A. The original design of the plant was for these vessels to receive also, at certain times, liquid metal from the cupolas, and they were so used occasionally during the time I had charge of the Bessemer works.

Q. 8. Am I correct, then, in understanding that at Sparrows Point the receiving vessels were supplied with molten metal at certain times from the blast furnaces and at other times from the cupolas?

Objected to because the statement of the question is not what the witness has stated in his last answer, and no such inference could be drawn from statements therein made. Therefore the question becomes leading.

A. Yes; you are correct in so stating.

212 Q. 9. State whether or not the semi-cylindrical receiving vessels at Sparrows Point revolved or turned about the axes of the cylinder.

A. Yes, sir; they did turn about the axis of the cylinder.

Q. 10. Am I to understand by your answer that the center or axis of rotation was the center of the cylinder?

A. The bottom part of these vessels was in the shape of a semi-cylinder. Supposing that to have been continued or prolonged to the completion of the cylinder, the center of rotation would have been the center of the cylinder.

Q. 11. State how the molten metal was delivered into and discharged from the receiving vessels at Sparrows Point.

A. The molten metal was brought over from the blast furnaces to these receiving vessels in ladles, and from them it was poured into the receiving vessels. The molten metal was poured out from the other side through a pouring spout by the movement of rotation of the vessel, which brought the spout below the level of the bath of metal.

Q. 12. What effect, if any, did the rotation of the vessel at Sparrows Point have as to agitating or mixing the contents?

A. The effect of agitation was very little, if any.

Q. 13. Will you explain for the benefit of the court, why the rotation of the Sparrows Point vessels had little or no effect in agitating or mixing the metal?

A. As the motion of rotation of these vessels was on the center of the cylinder there would be no vertical movement of the bottom of the vessel, but simply a movement in the direction of the periphery of the cylinder. The only effect on the bath of metal, therefore, would be that due to the friction between the periphery of the lined cylinder and the bath of metal. I think the effect of this method of pouring would be somewhat similar, if not exactly the same, as if a hole were cut through the vessel somewhere below the level of the bath and the iron allowed to run out through that.

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Q. 14. Say, as a matter of fact, whether or not the rotation of the Sparrows Point vessels had the effect of agitating or pitching about the fluid contents?

A. So far as I ever observed it had no such effect.

Q. 15. At the Sparrows Point works what means, if any, were used for keeping the metal in the receiving vessels in a molten condition?

A. An oil flame was blown in through one of the doors across the top of the bath.

Q. 16. Was this employment of a heating flame in the Sparrows Point vessels a continuous thing or not?

A. Yes, sir; it was.

Q. 17. Did you find the employment of this heating flame necessary to the practical working of the Sparrows Point vessels?

A. It was invariably necessary.

Q. 18. Please say whether or not the Sparrows Point vessels, as used with the continuous heating flame, were or were not in effect reverberatory furnaces?

Objected to as leading.

A. If these vessels had been provided with a smokestack they would have been practically reverberatory furnaces.

Q. 19. What difference would the stack have made in their action?

A. The stack would have given a better draught to have enabled a higher degree of heat to be maintained in the vessels.

Q. 20. Were the Sparrows Point vessels provided with a cover?

A. Each vessel was provided with a roof, and each pouring spout with a cover.

214 Q. 21. Describe the course of the heating flame in the Sparrows Point vessels.

A. It was introduced at a door situated at the axis of the vessel and spread itself out across the surface of the bath of metal, and the products of combustion then escaped under these covers.

Q. 22. In the Sparrows Point vessels, where was the air necessary for combustion obtained?

A. A portion of this air was blown in with the oil from a blower, and a portion was also drawn in by the suction of the combined air and oil jet.

Q. 23. During your service at Sparrows Point, from what sources was the metal obtained to charge the converters?

A. A portion was obtained from the receiving vessels and a portion from the cupolas.

Q. 24. Describe briefly the practice at Sparrows Point, during your service, as regards the manner of producing and delivering metal to the converters?

A. During week days all the metal produced at the blast furnaces from ores was run in the liquid state directly into ladles. These ladles were taken to the Bessemer works and their contents poured into the receiving vessels. In addition to this a number of cupola furnaces were kept in operation melting pig iron. The converters were charged by taking a portion of this liquid iron from the receivers into a ladle, and making up the balance of the requisite charge from this iron which had been melted in the cupola furnaces.

Q. 25. The ladles which received a portion of their charge from the mixing vessel and the remainder from the cupola for delivery to the converter were what is commonly known as a charging ladle?

A. It was usually called a charging ladle or iron ladle.

Q. 26. At Sparrows Point what was the practice as to maintaining a definite quantity of molten metal in the receiving vessels?

215 A. The quantity of metal kept in the receiving vessels varied very much, according to the amount needed for the supply of the converters; or rather to the number of ingots we wished to make per hour, and that was governed by the progress at the finishing mills. At times the receivers, one or both, would be entirely full, at other times entirely empty. My usual instructions were to take all the metal that was needed from the receivers, without reference to any particular amount they might have in them.

Q. 27. With what frequency did this fluctuation or variation in the quantity of metal in the receivers occur?

A. It occurred constantly during the twenty-four hours, and sometimes one or more might be nearly empty several times during that time.

Q. 28. Did any variation in the quantity of the product appear as a result of the varying quantity of metal in the receiving vessel?

A. No, sir; I never observed any.

Q. 29. Say whether or not, at Sparrows Point, you obtained satis-

factory results, notwithstanding the fluctuation in the quantity of molten metal in the receiving vessel and the fact that the vessel was occasionally nearly empty, as you have stated?

A. We did obtain satisfactory results.

Q. 30. Please examine the model now before you, and state, if you know, what it represents?

A. It represents one of the receiving vessels in use at the steel works of the Maryland Steel Co. at Sparrows Point.

Q. 31. Please say whether or not this model is a fair representation of the receiving vessel and ladles as used at Sparrows Point during the entire period of your service?

A. I think that it is.

The model referred to by the witness is offered in evidence and marked "Defendant's Exhibit No. 12, model defendant's receiving vessel."

216 Q. 32. Referring to the model Exhibit 12, please indicate by letters thereon the receiving vessel, the inlet for the heating flame, and the burner from which the flame is blown into the vessel?

A. I have marked the mixing vessel M, the inlet door for the flame D, and the burner B. The flame is blown through the small hole in the door.

Q. 33. Say whether or not this vessel M in Exhibit 12 is the same vessel you have referred to in your testimony as the receiving vessel?

A. This is the same vessel referred to.

Q. 34. At Sparrows Point, which was the exceptional practice, the using of metal from a blast furnace alone, or the using of metal from the blast furnace combined with that from the cupola?

A. It was the exception to use it direct from the blast furnace.

Q. 35. During your service at Sparrows Point was there any time when metal from the blast furnace alone was used for a prolonged period?

A. No, sir; there was not.

Q. 36. In a general way, what were the proportions of cupola metal and blast-furnace metal used at Sparrows Point?

A. The proportion of cupola metal used was considerably more than half; the proportion of blast-furnace metal less than half.

Q. 37. State the capacity of the blast furnaces at Sparrows Point, and with what frequency they were tapped?

A. At the time I was there the furnaces were, each one, producing about two hundred tons a day, and they were usually tapped about six times in twenty-four hours.

Q. 38. At each tap the blast furnace was emptied, was it?

A. Yes, sir; it was.

217 Q. 39. What advantage, if any, was there in using the receiving vessel at Sparrows Point as to equalizing the delivery of metal from the blast furnaces and to the converters?

A. The entire cast from the blast furnace could be immediately poured into a reservoir, thus saving considerable of the initial heat

and providing also a supply of molten iron to be drawn from whenever wanted.

Q. 40. About how many converter charges were tapped out of a blast furnace at one time?

A. About two converter charges, or at most three.

Q. 41. Was the quantity tapped from the blast furnace regular or irregular?

A. It varied considerably.

Q. 42. If you had not had the receiver or reservoir, what would you have been compelled to do with the surplus metal when the blast furnace was tapped?

A. Unless we had had a very large ladle the surplus beyond one converter charge would have had either to have remained standing a considerable time in the other ladles and consequently have given practical difficulties in crusting over and becoming chilled, or else the surplus would have had to be run on the pig beds.

Q. 43. Previous to 1888, what was the practice in the United States, if you know, as to mixing molten metal from different sources to get uniform converter charges; was that practiced or not?

Objected to as inadmissible under the answer, if it is proposed thereby to anticipate the invention of the patent in suit, as no time or place of use, or party alleged to have known such use, is stated in the answer.

A. It was the custom, so far as I know, universally, in Bessemer steel works to mix molten iron from several cupolas in a large ladle before converting the same, and also was quite the general practice in foundries.

218 Q. 44. Can you name any works in the United States in which this mixing of molten metals from different cupolas to produce converter charges was practiced in the United States prior to 1888?

Objected to for the same reason as the previous question, as no notice was given in the answer which would warrant the question, if the same is intended in any way to anticipate the invention in this suit, and that the present witness is not stated in the answer as having any such previous knowledge.

A. I have practiced this method of mixing molten iron from different sources at the works of the Cambria Iron Company at Johnstown, Pa., and those of the Bellaire Steel Co., at Bellaire, Ohio, previous to 1888.

Objection is made further to the following answer, so far as the Cambria iron works is concerned, that the reference in the answer to the Cambria Iron Company and its working, is insufficient, for the following reasons: First, that the Cambria Iron Co., being a corporation, can have no knowledge of any sort in regard to the matter; second, that the names of the workmen supposed to have such knowledge is not given, excepting Jacob Fritz, Simon Collin, Joseph Morgan, Jr., none of whom is the present witness, and that

no time is stated at which such previous knowledge or use occurred, and that no reference is given in the answer to any use at the Bellaire works.

This objection is made on the supposition that the testimony is offered to anticipate the invention of the patent in suit.

Q. 45. During what years did you mix the metals at the Cambria works and the Bellaire works, as stated in your last answer?

A. At the Cambria works, from July, 1881, until May, 1884; and at the Bellaire works, from about the first of the year 1886 up to 1890.

219 Q. 46. Say whether the mixing of different metals in the converter charges at the Cambria and Bellaire works was accidental or incidental to their mode of procedure, or whether it was done for some specific purpose?

Objection continued.

A. It was done intentionally and for a specific purpose.

Q. 47. Was such mixing at Bellaire and Cambria experimental or was it continued?

Objection continued.

A. It was continuous over the years referred to.

Meeting here adjourned to quarter of two for luncheon, when direct examination was continued by Mr. Dodge.

Q. 48. At Sparrows Point did your blast furnaces produce all the metal consumed by the converters?

A. No; there was a certain amount of pig metal bought from outside sources.

Q. 49. At Sparrows Point, what bearing, if any, did the use of the receiving vessel have on the continuous operation of the blast furnaces?

A. It enabled both of these departments to be operated continuously, providing an intermediate reservoir, the supply in which could be raised or lowered at will, so that a delay in either department would not necessarily effect the running of the other.

Complainant's counsel, reserving the objections already made to the questions put to the witness, proceeded with the cross-examination.

X Q. 50. You have spoken of the practice of mixing metal at the Cambria and Bellaire works previous to 1888. Will you please describe how that mixing was conducted, for what purpose and with what effect?

A. The mixing of cupola metal at Cambria was accomplished
220 by the tapping of a number of cupola furnaces into one large receiving ladle, from which converter charges were poured off and the supply in this ladle again increased by further tapping. The practice at the Bellaire steel works was similar to that. The purpose was to obtain a supply of metal for the converters to equalize

the different streams of metal from the different cupolas, and that was its effect. It accomplished that.

X Q. 51. Relative to the charge required for the converters, what was the capacity of this ladle?

A. This ladle would hold some 25,000 pounds. The converter heat at this time was seven and one-half tons.

X Q. 52. How was this ladle handled?

A. The ladle stood on a hydraulic ram, and it was elevated by means of this ram and poured by means of a gearing by hand power.

X Q. 53. Poured into what?

A. Into a runner leading into the converter.

X Q. 54. You have stated that the object was to equalize the charge; is that the object of the use of what you call the receivers in the Maryland steel works?

A. The main object of the receiving vessels at the Maryland steel works was as reservoirs of supply of iron.

X Q. 55. What means were used, if any, to prevent the mixing of metal from the various blast furnaces when poured into what you call the receivers at the Maryland steel works?

A. There were no means used to prevent the mixing of metal.

X Q. 56. Then I may assume, may I not, that the metal was mixed?

A. Undoubtedly.

X Q. 57. Prior to the year 1888 what was the practice in mixing metals from cupolas other than that which you have described?

A. I cannot answer that, it being an expert question.

221 X Q. 58. What experience did you have in using molten metal direct from blast furnaces prior to the year 1888 in converter practice?

A. None.

Redirect by Mr. DODGE:

Q. 59. Cupola metal is simply blast-furnace metal which has been permitted to solidify and then remelted in the cupola, is it not?

A. Yes, sir.

Testimony of Harry T. Morris.

HARRY T. MORRIS, witness on behalf of respondent, being duly sworn, deposes and says, in answer to interrogatories by Mr. Dodge, as follows:

Q. 1. State your name, age, residence, and occupation.

A. Harry T. Morris; age, 26; residence, Bethlehem, Pa.; occupation, at present in charge of the Bessemer and blooming departments of mill No. 2, Bethlehem Iron Co., Bethlehem, Pa.

Q. 2. Have you any connection with either of the parties to this controversy, or any interest in the result?

A. No, sir; I have not.

Q. 3. State briefly how long you have been connected with the iron and steel manufacture and what your experience has been.

A. From July, 1891, until August, 1893, with the Maryland Steel Company as stock metal weigher, in looking after the receiver, assistant foreman, and, finally, superintendent of the Bessemer department. Also in the summer of 1894 as designing engineer of the Pottsville, Pa., Iron and Steel Co., and from February 1, 1895, until the present with the Bethlehem Iron Company, in charge first of the rail department, and, finally, in the present position.

222 Q. 4. Examine the model Defendant's Exhibit 12, and state, if you know, what it represents.

A. It represents the vessel used in the Bessemer department of the Maryland Steel Company as a receiver for melted blast-furnace metal.

Q. 5. How many vessels like Exhibit 12 were used at the Maryland Steel Company at Sparrows Point?

A. During my service there there were two vessels; but one was used at a time.

Q. 6. State, if you know, when the receiving vessels like Exhibit 12 were put into use at Sparrows Point.

A. They were in use before I have any record. My first record as a hot-metal weigher is on February 4th, 1892.

Q. 7. Do you know whether any difficulty was experienced in using these vessels as first installed?

A. There was difficulty. As they were first installed there was no provision made for artificial heating, and we found difficulty owing to that, in the metal chilling on its surface; chilling in such large cakes that it obstructed the pouring.

Q. 8. How was the difficulty of the chilling of the metal in the Sparrows Point receiver overcome?

A. It was overcome by the introduction of an oil burner, which directed its jet over the surface of the metal, and, also, by the addition of covers over the pouring and receiving spouts, which had not been at first provided.

Q. 9. Say whether or not Exhibit 12 fairly represents the form and arrangement of the metal receiver and the burner for heating the same as used at Sparrows Point.

A. It does.

Q. 10. In pouring the metal from the semicylindrical receiver at Sparrows Point was there any material agitation or shaking of the contained metal?

A. There was not.

223 Q. 11. In pouring the metal, at Sparrows Point, from the semicircular receiver, was the receiver turned quickly or slowly?

A. It was turned gradually.

Q. 12. What was the practice at Sparrows Point as to keeping the molten metal at a fixed level in the receiver? Was this done, or not?

A. It was not a consideration at all to keep the metal at a fixed level. The level of the metal in the receiver was determined by the rapidity of drain on it to feed the converters.

Q. 13. As a matter of fact, to what extent did the level vary in the ordinary practice at Sparrows Point?

A. As a matter of fact, I have known days when the rolling mill was demanding product, when the vessel was continuously empty before the next following cast was charged or added from the blast furnace. When the rolling department was blocked, the vessel was so full that in order to empty our blast-furnace ladles, the metal has run out through the doors on the end.

Q. 14. Why was it desirable to speedily empty the blast-furnace ladles?

A. Because the iron in the ladles, if it stood any length of time, would chill across the top and on the sides of the ladle, and when the iron chilled on the side of the ladles, iron always remained in the bottom, making thick skull there.

Q. 15. What bearing, if any, did the receiver at Sparrows Point have on your ability to run the blast furnaces on the one side, and the converters on the other side continuously?

A. It was absolutely necessary to have a reservoir of metal in order to run both mentioned departments continuously, for the reason that each blast furnace at each cast will make from
224 two to three converter charges, and as we could only blow one at a time the balance of the cast would have to be delayed in the ladles.

Q. 16. During your service at Sparrows Point was it the usual or general practice to charge the converters with blast-furnace metal alone from the receiving vessel?

A. It was not.

Q. 17. What was the practice at Sparrows Point in this regard?

A. Our practice was to tap from the cupolas until they were drained into the iron ladle and make the balance of the converter charge from the receiver.

Q. 18. Then your ordinary converter charges at Sparrows Point consisted, in part, of cupola metal, and in part of blast-furnace metal; is that correct?

A. Nearly always so.

Q. 19. And at Sparrows this mixture of the blast-furnace metal and cupola metal for converter charges occurred outside of the receiving vessel or mixer, did it?

A. It did; it took place in the iron ladle or charging ladle.

Q. 20. Am I correct in my understanding that it was the practice to draw metal from two or more cupolas into the one charging ladle, and then add blast-furnace metal from the receiving vessel?

A. That is correct. We used sometimes two, and sometimes three cupolas.

Cross-examination by Mr. WILLIAM BAKEWELL:

X Q. 21. You spoke about there being cakes in the receiver before the use of the burner; were these cakes metal or slag?

A. They were a mixture of both.

X Q. 22. Have you any knowledge of a mixer being used in connection with the converter practice without heat being applied?

A. I have no knowledge of any other receiver, except that at Sparrows Point, personally.

225 X Q. 23. What is the reason why you always use the word receiver in connection with these mixers you use at Sparrows Point?

A. Because that is the name under which I always referred to it and under which it was always referred to by others.

X Q. 24. When the metal was poured into these receivers, was not the effect to mix the different charges of metal which were so poured in?

A. There was a mixture, provided there was any metal in the receiver to start with before the pouring.

X Q. 25. Is it not a fact that there was always metal in the receiver before the charge was poured in?

A. I suppose it might be said to be usual; very often there was.

X Q. 26. You have spoken about the practice of mixing cupola metal with blast-furnace metal for converter charges. Are you not aware of the fact that at the time when this was done they had at Sparrows Point a large amount of pig metal which required to be melted in a cupola before it could be used in the converter?

A. That was so in the first days of the operation.

X Q. 27. For how long a time during the period of your employment at Sparrows Point was this the case?

A. I should judge that, perhaps for four or five months before the end of my term there, we had recourse to foreign iron.

X Q. 28. Is it not a fact that, when they started the use of cupola metal for converter charges at Sparrows Point, that the blast furnaces they had were not large enough to supply the metal demanded for that purpose, and that they had to resort to the melting of pig metal?

A. It is true all through my experience there we melted pig metal in the cupola for use in connection with the other metal.

226 X Q. 29. Was it not for the reason stated in my previous question?

Objected to as being immaterial why the cupola metal was constantly employed, the fact appearing that it was so employed, in connection with the blast-furnace metal.

A. The blast furnaces did not have capacity enough to supply the converter.

X Q. 30. Was not the level of metal in the mixer determined by the supply from the furnaces as well as by the demand for the supply of the converters?

A. That depended upon circumstances. If the converters were not demanding metal for a period of time, the supply from the blast furnace had no bearing in the matter. If the converters were demanding metal rapidly, of course the level in the receiver was regulated by the supply from the blast furnace, as well as by the demand from the converters.

X Q. 31. What experience, if any, did you have in regard to the

use in converters of metal direct from the blast furnace before the use of the mixers at Sparrows Point?

Objected to as not in the line of cross-examination.

A. My experience in the converting department began after the use of the receiver.

Redirect examination by Mr. DODGE:

Q. 32. You have been asked respecting the oil burner in the receiving vessel at Sparrows Point. State whether or not the heat resulting from the use of that burner was sufficient to remove the sculls or solid accumulations.

A. The heat could be brought up to a sufficient pitch to melt iron in the receiver; I have myself melted or removed a scull from the pouring spout of the vessel with the burner that was in regular use.

Signatures waived by mutual consent of counsel.

227 Circuit Court of the United States, District of Maryland.

CARNEGIE STEEL COMPANY, LTD., *vs.* MARYLAND STEEL COMPANY OF BALTIMORE County and Frederick W. Wood, Receiver.	In Equity. Patent No. 404,414.

Testimony taken on the part of defendant under agreement of counsel, at the Astor house, New York city, N. Y., beginning this 18th day of June, 1896.

Present: J. K. Bakewell and William Bakewell, on behalf of complainant; P. T. Dodge and R. F. Rogers on behalf of respondents.

Testimony of Frederick W. Wood.

FREDERICK W. WOOD, witness on behalf of defendant, being first duly sworn, deposes and says in answer to the interrogatories propounded to him as follows, to wit:

Q. 1. State your name, age, residence and occupation.

A. Frederick W. Wood; age, 39; residence, Baltimore; occupation, president of the Maryland Steel Company.

Q. 2. State in a general way your experience with steel manufacturing.

A. I graduated from the Institute of Technology, Massachusetts, in 1877, in a course of mining, engineering and metallurgy, and that year entered the open-hearth department of the Pennsylvania Steel Company as a learner, remaining in that department in various capacities until 1880, when I was appointed superintendent of the blast furnaces. Held that position until 1883, when I was made assistant superintendent of the works; in 1884 superintendent of

the works, and in 1889 general manager; in 1891 president of
228 the Maryland Steel Company. The duties of the various positions required me to be practically familiar with the manufacture of steel as practiced by the Pennsylvania and Maryland Steel Companies.

Q. 3. The Maryland Steel Company you have referred to is the defendant in the present cause, is it not?

A. It is.

Q. 4. It has been testified that the defendant company uses at its works at Sparrows Point a certain receiving vessel into which charges of molten metal are tapped and from which the metal is drawn for use in the Bessemer converters. Please state briefly the principal use of the receiving vessel so used?

A. As a regulator between the blast furnaces, forming the source of supply of a part of the metal used in the converter, and for the converters to which the metal is delivered.

Q. 5. For what reason is it advantageous to use the receiving or accumulating vessel between the furnaces and converters?

A. To conduct the operations of the Bessemer department and mills which that department supplies with steel economically it is necessary that the deliveries of metal from which the steel is made should be as regular as possible. The blast furnaces, in case they form the source of supply, discharge molten metal at intervals of four or six hours, in quantities at each tapping sufficient for a number of Bessemer charges. The Bessemer blows or heats occur every fifteen or twenty minutes. The amount of metal taken from the blast furnaces at each tap is more or less variable, seldom the exact amount required for any number of Bessemer charges. Owing, therefore, to the different intervals of time and the great difference between the quantities drawn from the blast furnaces and required by the converter at any one time, a reservoir between the furnaces and the converter assists greatly in maintaining the routine and regularity of work.

229 Q. 6. Am I correct, then, in understanding that this receiver used by the defendant is in fact an equalizer between the irregular supply of metal on the one side and the irregular consumption on the other?

Objected to as grossly leading; the witness having said nothing of the sort and the question being designed obviously to instruct the witness as to what it is desired he should say.

Question withdrawn.

Q. 7. So far as the maintenance of the routine and the constant delivery of steel is concerned, does it make any difference from what source the molten metal is delivered to the receiving vessel?

A. Absolutely none.

Q. 8. Of what form are the receiving vessels used by the defendant?

A. Semicylindrical.

Q. 9. Is there anything in the form or motion of the defendant's

vessel to cause an agitation or mixture of the different charges which may be delivered thereto?

A. There is not. I do not think a form of vessel could be designed, or method of turning adopted, which could produce less agitation. The motion is imparted to the vessel by a hydraulic cylinder, causing the vessel to rotate very slowly about on its own axis.

Q. 10. Say whether you have seen these vessels of defendant in action, and whether or not as a matter of fact there is any agitation of the contained metal when the vessel is tipped to pour the metal therefrom.

A. I have frequently watched their working and have noted that the turning produces so little agitation that a slight scum on the surface of the metal would not be disturbed.

Q. 11. What has been the general practice in defendant's works as to the source of the metal going to the converters?

230 A. Practically all the metal used during the two years and three months when the works were in operation was obtained either from cupola furnaces or direct from the blast furnaces. This refers to the molten metal used in the converters. The iron drawn from the cupola furnaces having come primarily from the blast furnaces and been remelted in the cupolas.

Q. 12. Cupola metal is simply blast-furnace metal which has been allowed to solidify, and which has again been remelted, is it not?

Objected to as leading.

A. I intended my previous answer to convey that idea.

Q. 13. Is there any material difference in chemical organization between blast-furnace metal and cupola metal?

A. There is not.

Q. 14. Referring again to defendant's works, was it the usual practice to charge the converters solely with blast-furnace metal accumulated in the receiver or mixer?

A. It was not.

Q. 15. What was the usual practice in defendant's works in this regard?

A. To fill the ladle which delivered the charge of molten metal to the converter partly with iron tapped from cupola furnaces and partly with iron poured from the receiver, the iron drawn from the receiver having previously been brought from the blast furnaces in a molten condition and poured into the receiver. Occasionally also molten cupola metal formed a portion of the receiver's contents.

Q. 16. Then at defendant's works it was customary to accumulate in the receiver, not only blast-furnace metal but also cupola metal, is that true?

A. Generally the receiver contained only blast-furnace metal. Occasionally a proportion of cupola metal.

231 Q. 17. You have stated the advantage of the receiver as used with blast-furnace metal, did or did not these advantages exist when the receiver was used with cupola metal?

A. They did exist.

Q. 18. You have said the defendants generally obtained the converter charges by mixing the molten metal from the receiver in a ladle with molten metal from the cupola. Can you say approximately what portion of the steel manufactured during the use of the receiver was made in this way?

A. I cannot give exact figures, but know about nine-tenths of the steel was so made.

Q. 19. During the time the defendant's works contained the receiver, did you manufacture any steel directly from blast-furnace metal without the use of the receiver?

A. A little more than two per cent. About two and three-quarters per cent. of the 320,000 tons made while the works were in operation were made from metal brought direct from the blast furnace and empties into the converter without passing through the receiver. Most of this was during the first month the works were in operation when all machinery was in a more or less experimental condition and very small quantities of metal were wanted at regular intervals.

Q. 20. What was the practice at defendant's works as to keeping the intermediate receiving vessel filled with molten metal?

A. The quantity of metal in the receiver was allowed to fluctuate greatly.

Q. 21. Will you state in a general way the frequency and extent of this fluctuation?

A. There was no regularity. On some days it happened that the contents would fluctuate in quantity from 50 to 75 per cent. four or five times in 24 hours. On other days the level of the metal
232 in the receiver would be maintained for a number of hours at approximately one point. The fluctuation was governed entirely by the relation between the supply of the metal from the furnaces and the demands of the converters for additional charges.

Q. 22. You have referred to your experience in the works of the Pennsylvania Steel Co., at Steelton, Pa. Please say whether or not they used in those works, prior to 1888, any receiver or vessel between the source of molten metal and the converters; if so, state the fact.

A. They did. A receiving or charging ladle in capacity equal to, as I remember, two and a half converter charges. The source of molten metal for the converters in those works was four cupola furnaces, of which three were usually run at one time. The molten metal discharged from these furnaces in quantities varying from three to four thousand to seven or eight thousand pounds was accumulated in this ladle before being emptied into the converters. The average converter charge was about seven and a half tons. The capacity of the receiving or charging ladle was about 18 to 20 tons, I think nearer 20. In ordinary running the cupolas were tapped as soon as the metal had risen to or near the slag opening; two or three were frequently tapped simultaneously, and while the converter was being used with a previous charge, the cupolas were, as a rule, allowed to run empty, with the result that the receiving ladle was filled or nearly filled by the time the converter was ready

for another charge. The charging or receiving ladle was mounted on weighing apparatus and when the converter was ready such portion of the contents of the ladle as was needed for the charge was poured into a trough which delivered it to the converter.

Q. 23. Am I correct in understanding from your answer that in the Pennsylvania works molten metal was drawn from different sources into one ladle or receiver, and that from this ladle a portion of the combined or mixed contents were drawn away as a converter charge?

233 A. You are.

Q. 24. According to the figures you have stated a portion of the mixed molten metal charge remained in the vessel of the Pennsylvania works after the converter was drawn; is this true?

A. This is correct, invariably.

Q. 25. Now please say whether or not this remaining molten metal in the receiver was removed or permitted to remain during the refilling of the vessel?

A. It was.

Q. 27. How long did this apparatus continue in the Pennsylvania works?

A. It began with the starting of the works in 1867 and has continued to the present time, with some changes during that period in the actual capacity of the ladle and converters. The relative capacity of the receiving ladles and converters have remained nearly the same.

Q. 28. So far as the accumulation and mixing of the different charges of molten metal delivered into them are concerned in what way, if any, did the receiving vessel of defendant and that of the Pennsylvania Company differ in their functions?

A. In kind not at all. In degree dependent upon the difference between the size of the increments added to the mixing vessel and the quantity contained at the time of the addition.

Adjourned to 1.30.

Met pursuant to adjournment.

Q. 29. You have referred to the fact that the defendants sometimes placed molten cupola metal in the receiving vessels, why was this done?

A. This was only done when there was a quantity of molten metal in the cupola furnaces which we were obliged to dis-

234 pose of promptly without taking it to the converters. For example, when the steel mills were suddenly shut down through the breaking of a roll, or from other accidental cause, if two or three cupolas were in operation it was impossible to simply let them stand until the mills were ready to resume again. We, therefore, made it a practice to run the cupolas slowly, as slowly as possible consistent with keeping them in good order, taking the molten metal as it was tapped from them and storing it in the receiver to avoid the necessity of casting it into pigs and remelting a

second time. This practice should properly be considered accidental and not part of the routine.

Q. 30. Point out any resemblance or difference between the storing of the blast-furnace metal in the receiver when it was ready to be tapped and the storage of the cupola metal in the receiver when it was ready to be tapped, as you have stated?

Objected to, because there has been no testimony of this witness or in this case in regard to storage of metal, nor is it pretended, so far as it appears from the testimony of the witness, that the receiver was used as a storage vessel, as that would render it utterly useless for any of the purposes which have been described by the witness in his testimony.

Mr. DODGE: The attention of the court is called to the preceding question and answer.

A. There is no difference, as in either case the receiver serves to receive and hold the molten metal until wanted for use.

Q. 31. Throughout your testimony the intermediate vessel has been termed a receiver. How long has it been known by that name?

A. From the making of the first designs for the plant at Sparrows Point. I think the first sketches were made in the drafting room in 1886 or 1887.

235 Q. 32. State whether or not in defendant's plant there was any mixing of metals in the receiver, and if so, in what manner and to what extent?

A. Most certainly there was mixing. The same mixing that always takes place when two bodies of liquid capable of diffusing with each other are brought in contact. The same mixing that would occur if a bucket of water was emptied into a partly filled barrel of water. The same mixing that must of necessity occur whenever separate portions of molten metal are accumulated in a receptacle. A mixing which we could not prevent if we wanted to.

Q. 33. Please compare the mixing of the molten metal as it occurred in defendant's receiver with that which took place in the Pennsylvania works when different portions of molten metal were drawn into one vessel?

A. In both instances we have a receptacle lined with a refractory material in which separate portions of molten metal are successively placed. In case of the receiving or charging ladle at the Pennsylvania steel works the portions of molten metal are conducted from their source through troughs or runners. In case of the receiver at Sparrows Point, the separate portions of molten metal are brought in ladles and emptied in. The source of supply being too distant to admit of runners being used.

Q. 34. During the existence of receiver in defendant's works what proportion of the total amount of metal going to the converters passed through the receiver?

A. 29 and a fraction per cent.

Q. 35. Am I correct, then, in understanding that in defendant's

works less than one-third of the metal passed through the receiver to the converters?

A. You are.

This question and the preceeding one objected to as immaterial.

236 Q. 36. In defendant's works during the existence of the receiver what proportion of the metal used in the converters came from the cupolas without entering the receiver?

A. Sixty-eight and a fraction per cent.

Q. 37. In defendant's works what proportion of the metal was taken from the blast furnaces to the receiver and thence to the converters without the addition or admixture of other molten metals?

A. About between two and three per cent., I think, not exceeding three per cent. I think nearer two. I am certain not exceeding three per cent. as it was our almost invariable practice to fill the charging ladle of the converter with metal taken partly from the receiver and partly tapped from the cupola direct.

Cross-examination:

Complainant's counsel reserving the objection made to the testimony proceeds to cross-examine.

X Q. 38. How long is it since you began at the Sparrows Point works of the defendant to use the process of the patent in suit, involving the use of the Jones mixer?

Objected to as assuming that the practice of defendant is a practice covered by the patent in suit.

A. As I understand the Jones patent, we have never used the Jones mixer.

X Q. 39. According to your understanding of the patent in suit will you please state how the apparatus which you acknowledge to have used at the Sparrows Point works of the defendant differs substantially from the apparatus shown and described in the patent in suit, as you understand it?

Objected to as calling for opinion upon matters which rest wholly within the province of the court. Further, for the reason
237 that the witness has not been called as an expert in the patent matters or otherwise. It is suggested that if opposing counsel desires to follow this line of examination that he shall either make the witness his own or agree to accept the opinions he may express.

It is suggested by complainant's counsel to defendant's counsel that the latter refrain from instructing the witness as to answers he is to make by means of objections taken to the questions.

Mr. DODGE: The witness is instructed to exercise his own judgment in the answering or not answering this question calling for an expert opinion, according as he may or may not feel himself

qualified to pass on the subject. Further objection is made at this point that the question is unwarranted by the direct examination, and further that the patent in suit is not for an apparatus of any kind.

A. I will say in reply to that that I have not sufficiently clearly in mind to make such comparison the specific allusion in the patent in suit to the Jones mixer.

X Q. 40. Are you familiarly acquainted as a party to this suit with the questions of infringement involved in it and have you not frequently discussed with others the supposed difference or similarities, as the case may be, existing between the apparatus described (although not claimed in the patent in suit,) and that which has been in use at the works of the defendant?

Objected to as not proper cross-examination. The witness has not been qualified as an expert. Further objection that as the apparatus is, as admitted by opposing counsel, not claimed in the patent, his examination relative thereto is foreign to the issue.

A. I have discussed with counsel and others many of the points involved in the defense of this suit, but do not feel at all certain that I am familiar with them all.

238 X Q. 41. Have you not formed any opinion, not as a patent expert, but as a practical metallurgist, as to whether or not the apparatus and its mode of use, as existing and carried on at the works of the defendant, are or are not similar to the apparatus and its mode of use as described in the patent in suit? If you have not formed any opinion or judgment in regard to this matter you are, of course, at liberty to say so?

Objected to. First, as not being in the line of cross-examination; second, as calling for an expert opinion in matters regarding which the witness is not qualified; and third, as calling for a matter of opinion on which it is improper to interrogate the witness. He is instructed that he may answer or not, as he sees fit.

Complainant's counsel states explicitly that he does not want any expert testimony from his witness, but that as he is practically a party defendant to the suit, and has been testifying as to the differences between the apparatus there used and that used elsewhere, it is perfectly competent to ask his opinion as a practical metallurgist as to whether or not such apparatus and process are similar to, or dissimilar from, that described in the patent in suit, unless the witness will swear that he is not acquainted with the apparatus and process therein described.

Mr. DODGE: I will instruct the witness that he may answer or not as he pleases. That his opinion cannot be demanded on this matter according to the examination-in-chief.

A. My opinion is that the apparatus is entirely dissimilar and distinct from that which I remember as referred to in the Jones patent in suit. The method of using practiced at Sparrows Point, as I recall the spirit of the Jones patent, is also entirely dissimilar. I understand an essential element of the Jones patent, simply as a

practical steel manufacturer, to be the maintenance of an approximately constant body of metal in the receiving or mixing
239 vessel which is not allowed to fall below a certain minimum. This in no sense represents the practice at the Maryland Steel Company's works.

X Q. 42. Then I may assume, may I not, that the apparatus described in the patent in suit, and mode of using it therein described, are also in your opinion entirely dissimilar from the apparatus which you have described as having been used at the works of the Pennsylvania Steel Company, and its mode of use?

Same objection as to the preceding question and same instructions to the witness. Defendant's counsel disclaims any responsibility for the opinions the witness may express on subjects wholly foreign to those upon which he was examined in chief.

A. Both the apparatus and the method of using it at Pennsylvania steel works are different from the apparatus and the method of working at Sparrows Point.

X Q. 43. Now, please state whether the apparatus and mode of using at the Pennsylvania steel works, as you have described it, is substantially the same or substantially different from that in the patent in suit, as you understand it.

Same objections and instructions.

A. I should consider the functions of the apparatus similar such differences as occur being mostly differences in degree and quantities handled.

X Q. 44. Would you make the same answer as to the apparatus and mode of use at the defendant's works, and the apparatus and mode of use of the patent in suit?

Same objections and instructions.

A. No, I would not.

X Q. 45. Please explain further and how you would draw the distinction?

Same objections and instructions.

240 A. At the Pennsylvania steel works an approximately continuous operation is carried on, the receiving vessel being at intervals corresponding approximately to the frequency of the Bessemer blows, *being* partly emptied and refilled to the former level. The receiver used at Sparrows Point was filled at irregular intervals, and the withdrawals made at such intervals that the next addition of the metal more frequently than not failed to restore the level of the metal.

X Q. 46. This difference of regularity of charge and discharge between the operation at Sparrows Point and at the Pennsylvania steel works you regard as being an important difference, do you?

Same objection and instructions.

A. In the light of the wording of the patent.

X Q. 47. Will you please look at the patent and tell me what wording in it you refer to (handing witness patent)?

The question is objected to. The witness not having been interrogated respecting the patent and not having qualified as an expert regarding the patent, and he is instructed that he may answer or not as he sees fit.

A. I said in the light of the wording of the patent, which as I recollect, requires the constant retention of a considerable quantity of metal after pouring out a charge for the converter.

X Q. 48. And you state, do you, as of your own knowledge, that in the practice at the Pennsylvania Steel Company's works there was such a constant retention of a considerable quantity of metal after pouring out a charge for the converter?

A. My connection with the work in the Bessemer department at the Pennsylvania steel works was not such that I can say from my own knowledge and observation what quantity of metal was
241 allowed to remain in the ladle which received the metal from the cupola furnaces, but it is my understanding and belief that a considerable quantity always remained after pouring out a converter charge.

X Q. 49. And I understand you that such was not the case in the practice at Sparrows Point, do I, but that they always entirely emptied the ladle or receiver at every converter charge?

Objected to as misleading and unwarranted by the testimony.

A. I did not intend to convey such an impression. Generally there was metal left after pouring out a converter charge, and not infrequently the receiver was entirely empty, the fluctuations in quantity remaining in the receiver were, however, very great.

X Q. 50. And your direct testimony in this case has been based upon the conception which you have formed that a similarity or dissimilarity between any practice either at the defendant's works or at the Pennsylvania Steel Company's works and that of the patent in suit depended on the question as to whether the amount remaining in the receiver after a converter charge was substantially constant or fluctuating?

Objected to as not in the line of cross-examination, as calling for expert opinions, for which the witness was not qualified, and as unwarranted and misleading.

A. The testimony has been based wholly upon the facts, as I understand them.

X Q. 51. In the practice at the defendant's works you said that the amount left in the receiver as you called it, after a converter charge, was not always up to a certain level, or in other words, as you have expressed it, was fluctuating. Was this accidental or was it done with the view of avoiding, as you supposed, the use of the process described in the patent in suit?

242 A. It had absolutely no connection with the avoidance of the patent in question and was caused and controlled en-

tirely by existing conditions of supplies to and demand upon the receiver.

X Q. 52. Did not those same conditions involving the amount charged into and drawn out from the receiver of the ladle occur also at the works of the Pennsylvania Steel Company?

A. No, sir.

X Q. 53. Why not?

A. Because the supply and demand there was practically balanced in the amount and it was always possible to restore the level of the metal by the time another withdrawal was required.

X Q. 54. You have spoken in your testimony of a receiving ladle at the Pennsylvania Steel Company's works. Did you not mean by this what has been heretofore termed in this suit a charging or iron ladle?

A. Yes.

X Q. 55. Had you not a similar charging ladle in use at the defendant's works?

A. Not as I understand you to mean similar.

X Q. 56. Had you not a charging ladle in use at defendant's works?

A. Yes. A ladle into which the exact quantity of iron for one converter charge was run or poured, and which was completely emptied into the converter. The ladle was simply a conveyor from the source of the molten metal to the converter situated some distance away, being mounted on a truck to permit movement.

X Q 57. Now, what do you mean in that connection by the source of supply of the molten metal?

A. Either the reservoir of metal previously brought in a molten condition from the blast furnaces referred to before or from one or more cupola furnaces, or both.

243 X Q. 58. As a practical man, do you consider it good practice to run a stated amount of metal from the cupolas into the converter?

Objected to as calling for expert evidence.

A. Understanding that you mean to tap a stated amount of metal from cupolas and run it directly into the converter, I do not know as a practical man as any method of accomplishing it.

X Q. 59. It follows then, does it not, that the mixer or receiving vessel is a necessary adjunct to that mode of practice?

A. That mode of practice has been abandoned so long I should not like to express an opinion regarding it.

X Q. 60. I refer to the mode of practice at Sparrows Point which cannot be so very old that you have forgotten it.

Objected to, it not appearing what is meant by receiver or mixer in the question.

A. Will you kindly state more clearly the practice you refer to as we have never run metal from the cupolas into the converter at Sparrows Point.

X Q. 61. You have stated that at Sparrows Point the charging

ladle contained the exact amount of metal which was emptied entirely into the converter; you also stated as a practical man that it would be practically impossible to run metal from cupolas into the charging ladle in exact amounts. Under these circumstances does it not follow that the receiver is a necessary adjunct to such practice?

A. I did not state that we could not run metal from the cupolas into the charging ladle in exact amounts. I said we could not run metal from the cupolas into the converter in exact amounts.

X Q. 62. As a practical man do you consider it good practice to run a stated amount of metal from the cupolas to the charging ladle?

244 Objected to as not in the line of proper cross-examination and as incompetent, and that it calls for an expert opinion.

A. I see no objection to it under certain conditions.

X Q. 63. Under what conditions?

Same objection.

A. In works so arranged that when the tapping hole of the cupolas is stopped, the stream of metal will be accurately cut off from the ladle. This is a matter of disposition of cupola furnaces and means for handling and receiving ladle. In stating that there was no objection to such procedure, I had in mind the convenient obtaining of the exact amount for a converter charge. In case, however, sufficient metal was drawn from one cupola to form an entire converter charge, it is possible and probable that more or less irregularity in the character of the iron between successive charges would be encountered.

X Q. 64. Did you ever know of such cupola practice as is mentioned in the first part of your last answer, if so, where?

Same objection.

A. I think both the question and answer are hypothetical.

X Q. 65. Would it have been practically possible at Sparrows Point to draw an exact amount of metal into the ladle, using metal from the cupolas and emptying the ladle into the converter without also using the metal from the receiver?

A. Entirely so within the practical working limits of good practice.

X Q. 66. Did you ever do that?

A. Yes, sir.

X Q. 67. Under what circumstances? Was it regular practice or accidental?

245 A. It was not regular practice, yet could hardly be called accidental, for it was frequent. We had no other way of making charges entirely of cupola metal, and some months we ran entirely on cupola metal.

X Q. 68. Did you ever at Sparrows Point draw only from the cupola and not empty the ladle?

A. The only way that we could know the exact amount poured into the converter was to entirely empty the ladle.

X Q. 69. Do you mean that you always entirely emptied the ladle when drawing from the cupola alone?

A. The ladle was always so far turned that its mouth was lower than its bottom.

X Q. 70. Referring to question 13 direct and your answer thereto, please state if it is not a fact that cupola metal has to be higher in silicon than blast-furnace metal for use as a converter charge.

Same objection.

A. Other conditions being the same, no.

X Q. 71. How is it under ordinary practical conditions—the working?

A. In ordinary cupola practice, in the Bessemer steel works, only sufficient fuel is used in the cupola to barely bring the metal to the fluid condition. Blast-furnace metal as tapped from the furnace is usually somewhat hotter, therefore the difference in initial heat of the two classes of metal as delivered to the converter makes it desirable to have silicon a trifle higher in the cupola metal than in the blast-furnace metal. I believe, however, cupola metal containing not exceeding one per cent. of silicon has been successfully and regularly used, and so far as I am informed this is about the lowest practical limit for blast-furnace metal. In order, however, to obtain any possible advantage that may follow from the use of the hotter material from the blast furnace it is necessary to prevent the loss of this heat by quick transportation or storage in a large body very soon after it has been tapped from the furnace.

246 X Q. 72. Please answer the question in regard to sulphur.

Same objection.

A. Substituting sulphur for silicon I say no.

X Q. 73. Does not the metal take up sulphur from the cupola, and is not cupola metal therefore more highly charged with sulphur than blast-furnace metal?

A. That depends on the fuel which is used, the only possible source of sulphur in the cupola. With the selection of fuels available the addition of sulphur may be so small as to be of no consequence.

X Q. 74. The purport of your answer to question 13, as I understand it, was that in the converter practice it made no difference whether the charge of iron was taken from the blast furnaces or from the cupola. Is it not a fact that when iron is melted in the cupola for the converter a selection of the iron is made so as to get a charge of a desired and uniform character, whereas where the metal is taken from the blast furnace the product is very various constituents and not uniform even in the various tappings from the same furnace, so that the cupola metal will yield a much more uniform result than the blast-furnace metal?

Same objection.

A. I did not intend to convey more than I stated in answer to

question 13. So far as your question relates to the selection of pig metal for the making of cupola charges, so far as my knowledge and experience for the past ten years is concerned, it is the custom to unload cars of the metal promiscuously from a trestle or track, and take the metal from the pile so formed without reference to the varying character in a single cast or differences between consecutive casts of the differences between one day's work and another's. The regularity of the metal from the tapping hole of the blast furnace is chiefly a question of blast-furnace management.

247 Furnaces have been and are run giving iron as nearly uniform in different parts of the same cast and in successive casts as is drawn from the cupola, operated as is usually the case in the larger works.

X Q. 75. This practice which you have referred to as taking the pig metal from a pile promiscuously and charging it into the cupola and there melting it preparatory to charging it into the converter, practically obtains a mixture of various qualities of pig metal, does it not?

Same objection.

A. A mixture, resulting in the product not more uniform, however, than can be obtained by thoroughly good blast-furnace practice.

X Q. 76. The vessels which is used at Sparrows Point, and which you have called a receiver, has a capacity in practice of about how many tons?

A. When filled we considered the working limits about 100 tons. It could be made to hold about 120 tons, but this was inconveniently full.

X Q. 77. How frequently are you in the habit of tapping your blast furnaces?

A. At the times we have been using the receiver every six hours.

X Q. 78. How many tons of metal or quantity of metal did you draw from the receiver for a converter charge?

A. At the time the works were in operation a variable quantity.

X Q. 79. Give me about the quantity.

A. It varied very greatly from an entire charge of 15 tons down to one ton or even less, to adjust the weight of a charging ladle when accidentally the cupola did not deliver quite enough to make an extra converter charge.

X Q. 80. Then, as I understand it, you have and have had at Sparrows Point, in connection with your blast furnaces, a

248 vessel which you have called a receiver, and which is so constructed as to be capable of being tipped or tilted for discharging metal therefrom into a ladle to be carried to the converters, and that in this receiving vessel there has been poured, from time to time when the blast furnaces have been tapped, the amount of metal produced therefrom, irrespective as to time of the demands of the converters, but dependent on the time when it was usual or convenient to tap the blast furnaces and that from this receiver there has been drawn by pouring from it when tilted into a ladle

or ladles the necessary amount for a converter charge, and that this practice of pouring metal from the blast furnaces into the receiving vessel and drawing metal from the receiving vessel for the converter charges has been carried on practically continually; is not this correct?

Objected to as misleading, such not being the testimony.

A. As the storage tank or reservoir which I have spoken of as a receiver is semicylindrical and was rotated about its axis, "tilting" is hardly an accurate description of the movement, as that suggests the use of a more or less elongated vessel in which a surging action is set up by the tilting. We have, however, used for extended periods a storage tank or vessel such as I have described on direct examination, into which metal from the blast furnaces was poured at irregular intervals, and from which metal constituting from a small portion to an entire converter charge was taken at other intervals.

X Q. 81. You have in your testimony spoken about surging motion and on another occasion of agitation. Am I to understand that any special care has been taken to avoid agitation of the metal when it is either poured into or taken out from the receiving vessel, storage tank or mixer, whichever you may choose to call it?

A. There was necessary agitation due to pouring in the metal additions as there must be whenever one body of liquid is
249 poured into another. When, however, the metal was once in the receiver, we had no means of agitating it by the movement of the receiver.

X Q. 82. What would be the effect of a greater or less amount of agitation? Would it be desirable or injurious?

A. It certainly would not be injurious, and I doubt whether any material benefit would result.

X Q. 83. Will you state to me after careful consideration whether or not any precautions have been taken to avoid agitation, and if so, why?

A. Absolutely none. The form adopted for the receiver at Sparrows Point was chosen by me, as cheaply constructed and maintaining the body of metal in as compact form as possible. These are the only reasons for its adoption.

X Q. 84. State whether or not you ever saw the Jones mixer in operation, and if so, where?

A. I have seen it several times at the Edgar Thomson steel works.

X Q. 85. When first, if you recollect?

A. I cannot state positively.

X Q. 86. Was it when you were superintendent of the Pennsylvania works?

A. I think not; I think it was later than that; I should think somewhere about 1889 or 1890, but I am not at all certain as to the date.

X Q. 87. Had you any knowledge of it before you saw it—had you ever heard of it?

A. I think so; that is my impression.

X Q. 88. What was the average output of the blast furnaces at Sparrows Point?

A. During the period the steel works were in operation we had part of the time two furnaces and part of the time three furnaces in blast. The average daily output at that time was about 230 to 250 tons per furnace.

X Q. 89. And what was the average product of the converters?

250 A. That varied much, at times reaching about 1,200 tons per day, and other times down to 500 or 600 tons per day. There were also periods when the steel works were not in operation at all.

X Q. 90. Was that about the same practice that was had at the Pennsylvania Steel Company in regard to output?

A. No. The output at Steelton, as I remember, for those years was about 800 tons per day and fluctuated much less in quantity.

X Q. 91. What was the fluctuation—what percentage? About 10 or 15 per cent.?

A. Ten per cent. possibly. I should think hardly more than that.

X Q. 92. The output which you have stated for Sparrows Point seems to be very bad practice. Can you state what was the reason of it? I refer to the output of the converter.

A. That the first year was governed largely by causes existing in all new works. After that time chiefly by orders for the product of the mills. You will recall this was about the beginning of the financial depression.

X Q. 93. Was the output of the blast furnaces at Sparrows Point works ever equal to the demands of the converters, if the converters were run at the average output?

A. That would be very difficult for me to say without reference to our records, but I am certain that there were some days when the steel works were in operation in which the output of the furnaces was equal to the consumption of metal in the steel works.

X Q. 94. What do you understand to be the direct process as practiced previous to the introduction of the Jones mixer?

Objected to as incompetent; not in the line of cross-examination and calling for matters wholly foreign to anything on which the witness has been examined.

251 A. As generally understood in the trade it consisted in taking the molten iron required for the converter charges direct from the blast furnaces, as has been practiced for many years in Europe, and to some extent in this country.

X Q. 95. What, if any, experience did you have personally of the direct process prior to the introduction of the Jones mixer?

A. None.

The testimony of the witness as to the alleged use of the receiving vessel or ladle at the Pennsylvania Steel Company's works is ob-

jected to as it appears by his own admission that he had little or no personal knowledge of such use.

Redirect examination :

R. D. Q. 96. Referring to the practice at the Pennsylvania works, can you state from your own observation whether it was usual to leave any considerable amount of metal in the ladle after pouring the converter charge?

A. My duties as assistant superintendent and superintendent of the company required me to make frequent visits to all parts of the works. I have frequently seen the charging ladle containing a considerable quantity of molten iron after a charge had been poured into the converter, and am as certain as I can be of anything which I have not actually seen each time that was the usual and regular practice.

R. D. Q. 97. Can you say from your own knowledge whether at the Pennsylvania steel works it was the practice after pouring a converter charge from the ladle to empty out the remaining portion before refilling the ladle?

A. It was not. The additional metal required for the next converter charge was run into the charging ladle while it contained this balance from the preceding charge.

Redirect examination is continued without waiver of objections :

252 R. D. Q. 98. You were asked in cross-examination with reference to apparatus disclosed in the Jones patent in suit. In answering did you have in your mind more than one form of apparatus disclosed in that patent?

A. I had in my mind only the apparatus illustrated in the drawing attached to the patent.

R. D. Q. 99. Reference has been made to the fact that in defendant's works when using cupola metal alone you completely emptied the ladle into the converter. Was this done for a purpose, or because the works were not provided with weighing apparatus?

Objected to as leading.

A. The works were provided with weighing apparatus on which the charging ladle was mounted while receiving the metal for the converter charge from the cupolas or receiver or both. We were thus enabled to place in this ladle accurately the quantity required by the converter. Consequently the only way for us to know what charge was in the converter was to empty the ladle entirely, the converter being situated at a distance from the scale.

R. D. Q. 100. Referring to your answer 80 do you mean to be understood that it was the usual practice in defendant's works to draw the entire converter charge from the blast-furnace metal in the receiver?

A. Of the entire amount of steel made at Sparrows Point only a very small percentage, I think about three per cent., was made from metal exclusively drawn from the receiver.

Last question is objected to as utterly incompetent and immaterial.

R. D. Q. 101. At the defendant's works what was the usual proportion of metal drawn from the receiver and the usual proportion from the cupola added thereto of the converter charge?

253 A. The relative proportions varied so greatly that it is impossible to name a figure which could properly be called usual. During the entire period of operations, however, of the entire amount of iron used in making the 320,000 tons of steel, 68 per cent. and a fraction was drawn from the cupolas and 29 and a fraction per cent. from the receiver.

R. D. Q. 102. Are you either a lawyer or an expert in patent questions?

Objected to as immaterial.

A. Most decidedly not. I make no pretensions in either direction.

Recross-examination:

R. X Q. 103. State, if you please, what your relation to the defendant in this case is.

A. At the time this suit was brought I was receiver of this company.

R. X Q. 104. What pecuniary relation had you to this company; in other words, what is your interest in it?

A. Simply that of an executive officer.

R. X Q. 105. No pecuniary interest at all?

A. A very slight pecuniary interest in the Pennsylvania Steel Company.

R. X Q. 106. Are not the Pennsylvania Steel Company the owners of the defendant company?

The witness is instructed he need not answer.

R. X Q. 107. Or, at any rate, the owners of a large majority of the stock?

A. I decline to answer that question.

R. X Q. 108. Was all the metal from the blast furnace placed in the receiver at Sparrows Point?

A. No.

R. X Q. 109. What was done with it? Was it run into pigs or not?

254 A. On Sundays we run it into pigs, when the steel works were not in operation. I should say on Sundays and at other times when the steel works were not in operation.

R. X Q. 110. About how much was run into pigs, as you testified?

A. It would be impossible for me to state without reference to our records.

R. X Q. 111. Did you in your converters use any considerable

amount of pig metal in addition to that which was made on Sundays and at other times after the receiver was put in use?

A. Yes.

R. D. Q. 112. You have stated that a small portion of metal from the blast furnaces was put into the converters without going through the mixer? How often did this occur, do you recollect?

A. I think I stated it was confined mostly to the first month the works were in operation, and very seldom thereafter.

R. D. Q. 113. That is, very seldom after the receiver was put in operation, is that correct?

A. That is correct, because we used a very small quantity.

Signature waived by mutual consent.

Adjourned to meet at the same time and place Friday morning, June 19th, 1896.

255 Circuit Court of the United States, Western District of Pennsylvania.

CARNEGIE STEEL CO., LTD., vs. CAMBRIA IRON CO. } No. 2, May Term, 1896. In Equity.

Depositions of witnesses and other evidence on part of defendant taken at the office of Kay & Totten, No. 96 Diamond street, Pittsburgh, Pennsylvania, commencing on Tuesday, Nov. 17, 1896, at 11 o'clock a. m., before Robert C. Totten, notary public and special examiner, by agreement of counsel, the depositions being taken at a time and place agreed upon by counsel.

Present: J. K. Bakewell, Esq., and William Bakewell, Esq., on behalf of complainant, and James I. Kay, on behalf of defendant.

Defendant's counsel offers in evidence the following depositions taken on behalf of the defendant in the suit of Carnegie Steel Co., Ltd., the present complainant, against the Maryland Steel Co., of Baltimore, and Frederick W. Wood, receiver, said suit having been commenced on or about October, 1893, to wit: The depositions of John R. Whitney, Adam J. Frederick, Harry H. Campbell, Jacob B. Martin, Homer A. McGarvey, F. P. Hershey, T. G. Wolf, George F. Barnard, J. W. Cabot, Harry T. Morris and Frederick W. Wood.

Also, all the exhibits referred to in the said several depositions, including drawings and models.

256 *Testimony of David E. Spielman.*

DAVID E. SPIELMAN, a witness called on the part of defendants, and being first duly sworn, deposes as follows in answer to questions put to him by Mr. Kay:

Q. 1. State your name, age, residence and occupation.

A. David E. Spielman; 47; Altoona; assistant foreman Pennsylvania Railroad Wheel Foundry at Altoona.

Q. 2. How long have you been employed in that wheel foundry?
A. I went into the employ of the Pennsylvania Railroad Company in 1870 in the iron foundry; I was promoted afterwards into the wheel foundry about 1874 as wheel-molder; then, about 1879, I was promoted as assistant foreman.
Q. 3. Can you produce a drawing which would show about the plan of that wheel foundry as it was when you became employed there?

Plan of foundry objected to as it does not appear to have any relevancy to the matters in issue in this case.
Mr. Kay suggests that if Mr. Bakewell will wait a few minutes he will learn why the question was put.

A. Yes, this is it. (The drawing referred to by the witness is offered in evidence and is marked "Defendant's Exhibit Plan Altoona Wheel Foundry.")

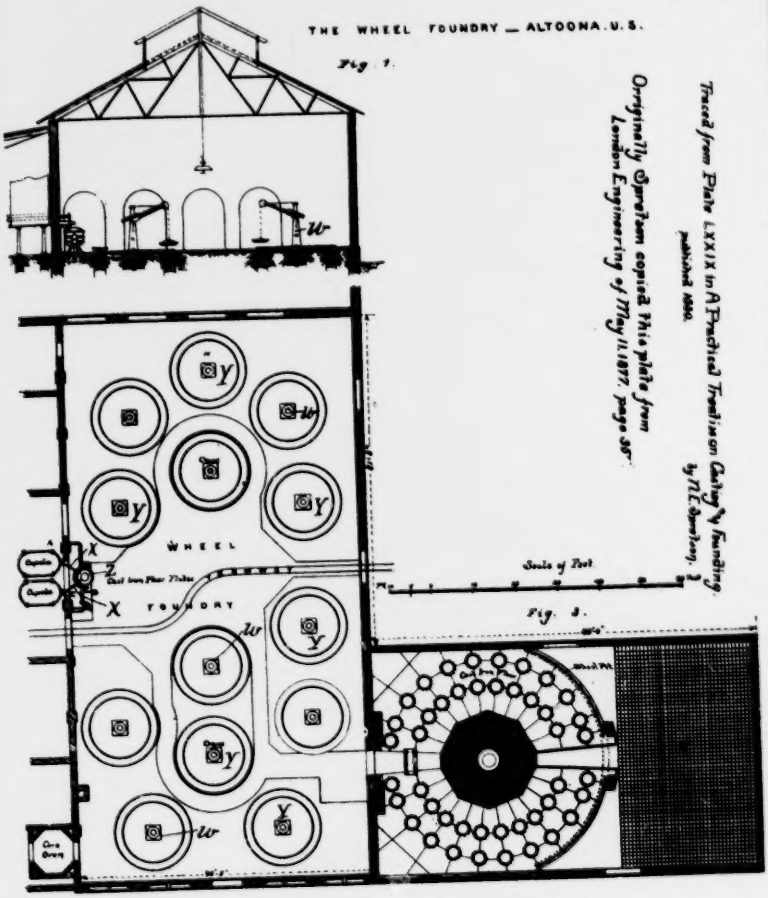
(Here follows diagram marked page 256*a*.)

Objection continued.

Q. 4. When you first went to work in that wheel foundry how many cupolas did they employ?
A. Two.
Q. 5. Was the metal from these cupolas tapped directly from the cupola into the ladle which was carried to the wheel mold?
A. No, sir.
Q. 6. Please describe the way in which the metal was handled in taking it from the cupolas to the molds.
257 A. In the first place it was run into a reservoir or large ladle which would hold about seven tons, then it was poured from the reservoir into small ladles which would hold about 700 pounds each, then taken from there direct to each floor.
Q. 7. What was done with the metal when it was taken to each floor?
A. It was left then to the discretion of the molder and whenever he thinks it is cool enough, and then it is poured direct into a wheel mold.
Q. 8. About how much metal does each wheel mold require?
A. About 700 pounds.
Q. 9. Does the plan which you produced show the positions of the cupolas and the reservoir to which you have referred?
A. Yes, sir.
Q. 10. Will you please point them out on the drawing?
A. These are the McKenzie cupolas, of which there are two each marked "cupola" on the plan; each of these cupolas has a runner indicated in the plan leading down to the reservoir in dispute, which I now mark Z. The metal is poured from this reservoir into the small ladles or buggies and is run around to the wheel floors, which are indicated by the circles marked Y, where it is turned over to the wheel-molder.

United States Circuit Court
Western District of Pennsylvania.
Carnegie Steel Co. Limited
-vs-
Cambria Iron Co

Defendants Exhibit
Plan Altoona Wheel Foundry
Robt. C. Totten
Examiner



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Cambria Iron Co.
} p. 256a

Q. 11. I notice in the center of each wheel floor a square mark with a circle within it; what is that intended to represent?

A. The hydraulic crane, which I now mark W; it is shown in Fig. 1.

Q. 12. What is the part of the plan, the lower right-hand corner?

A. It shows the room with the annealing pits.

258 Q. 13. Can you produce a drawing showing the reservoir into which the metal was tapped from the two cupolas, as you have stated?

A. Yes, sir. This is it.

The drawing referred to by the witness is offered in evidence and is marked "Defendant's Exhibit Drawing Altoona Reservoir."

Former objection continued.

Q. 14. Please state the way in which this reservoir or large ladle was moved in pouring the metal from it.

A. The ladle turns on two trunnions and has chains leading from these trunnions down to the hydraulic cylinder shown on the drawing, one chain being wound in one direction on one trunnion and the other being wound in the other direction on the other trunnion, and the two chains being connected at opposite ends of the piston-rod.

Q. 15. Will you please now describe the way in which the metal is melted in the cupolas and conducted to this reservoir, for use in filling the small ladles, stating your regular way of working each day, and describing the operation from the time of starting the cupolas until the end of the blow?

A. In the first place each cupola is charged with about 40 tons of metal. We charged about 40 tons in each cupola; then after we have this done we put the blast on and begin to melt, and as soon as ever the bed in the cupola is filled up with molten metal we tap it out into the receiving ladle or reservoir, which fills the reservoir about one-half full, then we stop the cupolas up again until the iron raises to the eye-holes, then they are tapped again, and this second tap generally fills the reservoir; then after the reservoir is full, we begin to pour the metal out into smaller ladles, then send it around to the molders for pouring into the wheel molds.

259 Q. 16. About what time each day do you turn on the blast on the cupolas?

A. Usually about eleven o'clock.

Q. 17. About how long after that have you the ladle full, ready for pouring into the wheel molds?

A. About forty-five minutes.

Q. 18. How long each day do you keep on the blast?

A. About five hours and a half.

Q. 19. About how often do you tap the metal from the cupolas into the receiving ladle?

A. About sixteen times.

Q. 20. About how many tons of metal do you usually melt in the

two cupolas and pass therefrom into the receiving ladle and tap from the same into the small ladles each day?

A. From 76 to 80 tons; it depends on the size of the wheels cast.

Q. 21. Do you tap the two cupolas simultaneously, or at different times?

A. We try to tap them both at the same time.

Q. 22. What is your custom as to the pouring of the metal from the receiving ladle into the small ladles—to what extent do you empty the receiving ladle?

A. We empty the receiving ladle about one-half.

Q. 23. Then, after it is so emptied, what do you next do?

A. We then hold the remainder of iron in the reservoir until the cupolas are ready to be tapped again.

Q. 24. And then what do you do next?

A. After the reservoir is full we start and pour out into the smaller ladles again.

Q. 25. You say that you tapped the cupolas about sixteen times a day, and you say that you empty the receiving ladles about one-half; now please state whether there is any metal remaining in the receiving ladle when you tap the cupolas.

260 A. The receiving ladle at all times is kept about one-half full.

Q. 26. And is it this full when you tap the metal into it from the cupola?

A. Yes, sir.

Q. 27. And about to what extent do you fill it each time you tap the cupolas?

A. If our cupolas is working properly we fill it each tap.

Q. 28. Has it been the custom to operate this foundry in the way you have described since you became assistant foreman?

A. Yes, sir.

Q. 29. Has there been any change in the way of working in the melting of the metal and the passage of the same into the receiving ladle since you became assistant foreman?

A. I don't understand that question.

Q. 30. I mean, have you made any change in the general way of working the foundry, including the melting of the metal and taking of the same from the cupolas into the receiving ladle and then into the smaller ladles since you became assistant foreman?

A. No, sir; the metal is taken from the cupola in the same way that it was years ago.

Q. 31. What kind of wheels have been formed in this foundry?

A. Cast iron double-plate chilled car wheels.

Q. 32. Was any advantage obtained in passing the metal from the two cupolas into the one receiving ladle before it was fed into the smaller ladles?

A. Yes, sir; we think so.

Q. 33. Please state what that advantage was.

A. By so doing we get a more uniform mixture.

Q. 34. What advantage is that in the manufacture of chilled-iron car wheels?

261 A. There was one word in the answer that I would like to alter, I should have said more uniform results.

Q. 35. In what way do you get more uniform results?

A. In this way we have about 7 tons of iron to take our test from, and we are satisfied that the larger the body of iron the more uniform the mixture will be.

Q. 36. What is the usual class of metals which you charge into the cupolas?

A. About 40 per cent. of the best charcoal pig irons, and 5 per cent. of steel, and 10 per cent. of anthracite pig metal, and about 45 per cent. of scrap, I mean old car wheels.

Q. 37. Do you find that the two cupolas always melt down regularly?

A. No, sir, not always.

Q. 38. Please state about the action of the cupolas and what leads to irregularity?

A. There is different reasons why the cupolas do not work together. In the first place the tapper may allow the metal to rise too high and run in the tuyeres, and in the second place the boshes may cut, and, third, oftentimes we have very bad fuel to contend with.

Q. 39. Do any of these lead to irregularity of the quality of the metal produced?

A. Yes, sir.

Q. 40. Please explain this more fully, so that the court may understand?

A. Oftentimes what we call the chill test runs too high; now there is various reasons lead to this. If there is too much sulphur in the fuel it will cause hard dense iron, and if the fuel gets burnt out too soon, then the iron becomes cold, or in other words, the iron bridges in the cupolas. If we have a very high test, of course, we will have correspondingly hard wheels.

Q. 41. You refer to the chill test running too high; will you explain what that means, and how the fact that it runs too high is shown by the test?

262 A. Do I understand you want to know how we know the test is too high?

Q. 41½. Yes.

A. By simply breaking the test in two pieces after it is cast shows the chill on the test.

Q. 42. How is the fact that the chill is too high indicated in the appearance of the chill?

A. We always like to have one inch of solid white iron on the test and a good open-grained iron back of it. Suppose we had an inch and a quarter of white iron, then we would have too much.

Q. 43. Then your object is to get the uniform thickness of one inch of chilled metal?

A. Yes, sir.

Q. 44. Are these the uniform results to which you referred before

in your testimony as to the advantage in the use of the receiving ladle?

A. Yes, sir. After taking the test we judge our wheels accordingly.

Q. 45. Please state how often you take these tests.

A. We take one from each tap from the cupola.

Q. 46. Now please describe what you take the metal directly from in making the test?

A. We catch the test from the reservoir when it is full, tapping it into a small ladle and then pouring it into the test.

Cross-examination by Mr. WM. BAKEWELL:

X Q. 47. What experience, if any, have you had in the direct process of the Bessemer practice?

A. I don't know what you mean by Bessemer practice.

D. E. SPIELMAN.

Adjourned to meet at same place Wednesday, Nov. 18, 1896, at 10.30 a. m.

263 Met pursuant to adjournment.
Present: Counsel as before.

DAVID E. SPIELMAN recalled for further cross-examination at the request of complainant's counsel:

X Q. 48. You have produced a drawing alleged to show about the plan of the wheel foundry of the Pennsylvania Railroad Co. at Altoona, as it was when you became employed there. State if you know who made that plan.

A. No, sir; I do not.

X Q. 49. You have spoken of the practice at the wheel foundry of the Pennsylvania Railroad Co. as it was when you first went there. Am I to understand that no changes have been made in that practice from that time to the present?

A. I would state that the foundry was not built until three years after I was first employed there.

X Q. 50. When you were first employed as the assistant foreman about the year 1879, the foundry, as shown in the drawing which was produced, was then in operation, was it not?

A. It was.

X Q. 51. And the plant shown in the drawing and the practice thereunder, as you have described it, has continued the same from that time to the present time, has it?

A. About the same, yes, sir. There have been a few modifications.

X Q. 52. Do those modifications refer to the plant or to the practice in use in the plant?

A. No, sir; they do not refer to the plant; they refer to the charging of the cupolas.

X Q. 53. You have stated that the cupolas were tapped as near

as possible at the same time. Were the cupolas charged at the same time or at different times?

A. It was our practice to charge them together as near as possible.

X Q. 54. And the charge in each cupola was the same each time, was it not?

264 A. Yes, sir.

X Q. 55. You have stated in your answer to the 35th question that the charge of the cupolas was usually about 40 per cent. of the best charcoal iron and 5 per cent. of steel and 10 per cent. of anthracite pig metal and about 45 per cent. scrap. Where were the charcoal iron and steel manufactured with which you charged the cupolas?

A. Part of the charcoal iron we get from Connecticut, part of it comes from Alabama, and the remainder from Pennsylvania. As to the old steel rail, I am not able to say where it was manufactured.

X Q. 56. What was the capacity of each of the two cupolas you have referred to? I mean by capacity the size of the hearth of part of the cupola in which the molten metal was received before the cupola was tapped?

A. I can't answer that question positively at the present time, I can give you a rough estimate. The inside dimensions of our cupola as near as I can tell at this time are about 4 by 8 feet, they are oblong; the bed is about 12 inches deep.

X Q. 57. You have called these cupolas McKenzie cupolas, what do you mean by that?

A. Because the maker's name is stamped upon the cupolas.

X Q. 58. Do they differ in construction from ordinary cupolas, so far as you know?

A. Yes, sir, they do in some respects.

X Q. 59. Can you state how?

A. Yes, sir. The McKenzie cupolas have continuous tuyeres.

X Q. 60. These cupolas are used simply for the purpose of melting the charge of combined charcoal pig, anthracite pig and scrap for the purpose of casting car wheels? Were they not?

A. That is what we use them for.

265 X Q. 61. You have spoken of taking tests from the cupolas, how often was this done?

A. We don't take the tests from the cupolas, we take the tests direct from the reservoir.

X Q. 62. What were the internal dimensions of the reservoir of which you have spoken?

A. We have a print here giving the exact dimensions. I cannot give it. I can give a rough estimate, about 4 foot in diameter, 6 foot high. It was circular and tapered at the bottom.

Redirect examination:

R. D. Q. 63. Please state about how often you took a tap from the reservoir to make the tests about which you testified?

A. It was our custom to take a test from the reservoir every time

the cupolas are tapped in; if the cupolas are working free the taps come much oftener; if they are working slow, the taps are longer apart. As a general thing they are about every 20 minutes.

R. D. Q. 64. Am I to understand that to make this tap you turned the reservoir so as to pour out of the pouring opening near the top thereof?

A. Do you mean to make the test?

R. D. Q. 65. Yes, to make the test, or to pour the metal out of the reservoir into the smaller ladles for casting the wheels.

A. Yes, sir; we turn it forward far enough to take out the amount of iron desired.

R. D. Q. 66. About how soon after you have tapped the metal from the cupolas into the reservoir to refill it, do you tap out the metal for making the tests?

A. As soon afterwards as it is possible to do it.

Recross-examination:

R. X Q. 67. What was the object of making the tests you have spoken of?

266 A. So as to know what kind of wheels we are turning out. And also to determine the chill on the wheels.

R. X Q. 68. You were careful, I suppose, as to the quality and kind of iron with which you charge the cupolas, are you not?

A. Yes, sir; we are.

R. X Q. 69. On that depends, largely, the quality of the wheels you cast, does it not?

A. Yes, sir; it does.

R. X Q. 70. You were not in the practice of running into the reservoir melted metal direct from the blast furnace, were you?

A. No, sir; we have no blast furnace.

R. X Q. 71. You stated that you had two cupolas; do you always run them both at the same time or do you sometimes use one only?

A. We always run the two cupolas together, unless there is an unavoidable accident, and something should happen to one or the other cupola. This doesn't occur once in five years.

D. E. SPIELMAN.

267 *Testimony of Daniel W. Osbaugh.*

DANIEL W. OSBAUGH, a witness called on behalf of defendant, being first duly sworn, deposes as follows in answer to questions put to him by Mr. Kay:

Q. 1. Please state your name, age, residence and occupation.

A. Daniel W. Osbaugh, 46 years; Altoona, Pa.; molder.

Q. 2. Where do you work and how long have you been employed there?

A. At the present time I work in the wheel foundry at the shops of the Pennsylvania railroad in Altoona; I have been employed by the company since February, 1871.

Q. 3. How long have you been a molder in the wheel foundry of the company?

A. Since 1880.

Q. 4. Are you acquainted with the practice in that foundry as to the way they melt the metal for casting car wheels, and handle it from the cupolas to the molds?

A. I am.

Q. 5. Please describe the way the metal is taken from the cupolas and finally poured into the molds.

A. It is taken from the cupolas and deposited in the reservoir by a conductor called a "runner," and then when the reservoir becomes full, we then take a smaller ladle and run it up to the reservoir, as they pour out the first wheel we take a test over that ladle, and then the ladle is taken to the mold. Then the molder takes and pours the wheel.

Q. 6. How many cupolas have you in regular use in the foundry?

A. Two in the wheel foundry.

Q. 7. Are those both tapped into the same reservoir?

A. Yes, sir.

268 Q. 8. About how often during the day are they tapped into the reservoir?

A. About 15 times, I think.

Q. 9. At intervals of about how many minutes?

A. Anywhere between 15 and 20 minutes.

Q. 10. About what is the capacity of the reservoir, as you term it?

A. About 7 tons.

Q. 11. About what is the weight of each wheel casting made?

A. We have two kinds of wheels, one 33 inch in diameter and the other 36 inch in diameter; the weight of the 33-inch wheel is about 570 pounds; the 36-inch wheel is 690 pounds.

Q. 12. In drawing the metal from the reservoir into the smaller ladles, do you draw metal for more than one wheel at a time?

A. Each ladle is to hold enough for one wheel.

Q. 13. After the reservoir has been filled with the metal, to what extent do you empty it before tapping into it again from the cupolas?

A. About one-half.

Q. 14. Then I would understand that between the taps from the cupolas into the receiving ladle, you take out a sufficient number of smaller ladles full to pour about 3½ tons of wheels?

A. That is correct.

Q. 15. About how many wheels do you usually cast as a day's work?

A. We have thirteen floors with eighteen wheels on each floor, which makes 234 wheels.

Q. 16. Can you identify drawings showing plans of the wheel foundry and of what you call the reservoir therein?

A. Yes, sir. This is a correct plan of the wheel foundry. (Witness refers to "Defendant's Exhibit Plan Altoona Wheel
269 Foundry.") Those two are the cupolas, each marked "cupola;" those are the runners which I mark X, which

convey the metal to the reservoir: this is the reservoir marked Z. The general construction of the ladle is shown in "Defendant's Exhibit Drawing Altoona Reservoir."

Q. 17. After you have poured about one half the metal out of the reservoir to what extent do you fill the reservoir before tapping out any more into the smaller ladles?

A. We fill it up again by tapping the cupola.

Q. 18. How long has it been the custom to handle the metal from the cupolas to the molds in the way you have described?

A. Ever since the wheel foundry started. I wasn't working in the wheel foundry at the time it started. I was under the same roof in the capacity of soft-iron molder.

Q. 19. Have they used the same reservoir during all that time?

A. They have.

Q. 20. What kind of wheels have they cast with the metal melted and handled the way you describe?

A. Chilled-iron car wheels.

Q. 21. Was any advantage obtained in passing the metal from the two cupolas into one receiving ladle before it was fed to the smaller ladles and taken to the molds?

A. The advantage is, they think, we got a more uniform mixture.

Q. 22. What advantage is that in making the car wheels?

A. Well, we are very particular to have the mixture as near right as possible. The advantage is, I think, we get a more uniform test of the iron.

Q. 23. What does that test indicate?

A. It indicates strength and weakness; if it is too high the chances are we have brittle wheels, and if too low, we have a soft wheel.

Q. 24. How does the test that you make show the condition of the iron?

270 A. By breaking it. The fracture inside will show you the amount of chilled iron on the test.

Q. 25. Does that indicate anything as to the wheels cast, and if so, what?

A. If we have a one-inch chill test of white iron, the indications are we have good wheels.

Q. 26. Can you state why the custom is to pour only one-half of the metal out of the reservoir before refilling it?

A. The custom is that the bed of both the cupolas only holds about the amount required to fill half the reservoir.

Q. 27. Can you state whether the cupolas always run regularly?

A. As near as can be possible.

Q. 28. Is there ever any variation in their action as to the amount of metal one melts down as compared with the other?

A. There is a slight variation sometimes; they are both charged with the same amount of metal.

Cross-examination by counsel for complainant:

X Q. 29. You were present yesterday and today during examination of Mr. David E. Spielman, were you not?

A. Yes, sir.

X Q. 30. Mr. Spielman stated that in the practice with the plant referred to by you and by him as in use at the car wheel factory of the Pennsylvania railroad at Altoona, there had been some modifications which referred not to the plant but to the charging of the cupolas. If you know of such modifications, please explain what they were.

A. Mr. Spielman is better acquainted with those modifications than I am; he has direct charge. I don't know particularly what those slight modifications are.

X Q. 31. Do you know in what way the cupolas were charged and with what material?

271 A. I do to a certain extent. I know they were charged with charcoal pig iron and anthracite pig iron, steel and scrap, old wheels.

X Q. 32. You have spoken about some irregularities in the product of the two cupolas, one from the other as I understand it, and this irregularity has been explained by Mr. Spielman as arising from some or all of three causes, that the tapper might allow the metal to rise too high so as to close the tuyeres. What effect would that have on the quality of the product, if you know?

A. Well, it would have very little effect, in my opinion. It would stop the flow of blast to a certain extent. The cupola would melt slower.

X Q. 33. A second cause stated was that the boshes might cut; what effect, if you know, would that have on the quality of the product?

A. I can't answer that.

X Q. 34. A third reason given was the use of bad fuel; what effect, if any, would that have on the quality of the product?

A. Bad fuel, we term too much sulphur; it seems when there is more or less sulphur in the coal the test will run a little higher.

X Q. 35. I understood you to say that the cupolas were charged usually at the same time and with the same ingredients. Is it not also true that the same fuel would be used in both cupolas at the same time?

A. We try to do that as near as possible.

X Q. 36. Under these conditions, with the cupolas charged about the same time with the same material and the same fuel used, would not the ordinary result be that the product of the two cupolas would be similar in quality, as the result of such charges?

Defendant's counsel suggests that the witness is not called as an expert cupola workman, but is called as to a question of fact.

272 A. I will answer that question this way: While I know those cupolas are charged as near as possible the same every day, we sometimes find a little variation in the product.

X Q. 37. Do you mean that you find a variation of the product of the same cupola tapped at different times, or do you mean there is a difference in the product in different days?

A. We take one day's work; we will start out by breaking the

first test; that test may measure one inch, perhaps the next test when broken will measure $\frac{15}{16}$ of an inch, and so on. The variation, I want to show you, is very slight.

X Q. 38. Have you any means of determining whether the product of one cupola differs from the product of the other cupola?

A. No, sir.

X Q. 39. As you take your test from the metal in the reservoir and not from the metal drawn direct from the cupolas, you have no means of determining the quality of the metal used at a given time from each of the cupolas, have you?

A. No, sir, I have not.

X Q. 40. You have spoken of the object of the test being to ascertain whether the metal was too high and consequently too brittle, or too low, and consequently too soft. As I understand it, then, the purpose of the test is to ascertain the amount of carbon contained in the metal, is it not?

A. I suppose it is; I am not an expert. I will just state when our metal is running a little too high we have a remedy; by putting a small amount of ferro-ma-ganese in each ladle for each wheel. For soft iron, or low chill, we have no remedy.

X Q. 41. Do you sometimes attempt to correct the iron as to its being too high or too low by adding anything to the metal in the reservoir?

A. We never add anything to the reservoir.

DANIEL W. OSBAUGH.

273 *Stipulation.*

Now, Nov. 18, 1896, it is agreed by counsel for the respective parties that the defendants' answer in this cause may be amended by inserting after the list of publications pleaded under paragraph 8 of said answer, to wit, at the foot of page 11 of the answer, as filed, the following:

An article appearing in the Pittsburg Daily Commercial under date Feb. 12, 1864, relating to the casting of a gun with a calibre of 20-inch diameter at the Fort Pitt works.

An article entitled "The direct use of blast-furnace metal in the Bessemer process" by A. L. Holley, New York, 1877, being also marked "No. 11 and Second Series."

The above stipulation is made with the understanding that it is not to be taken as an admission on the part of complainant that either of said articles is a printed publication within the meaning of the statutes in relation to patents.

Adjourned to meet at same place Thursday, Nov. 19, 1896, at 10.30 a. m.

274 Met pursuant to adjournment.
Present: Counsel as before.

Testimony of Andrew J. Cupples.

ANDREW J. CUPPLES, a witness called on the part of defendants and being first duly sworn, deposes as follows in answer to questions put to him by Mr. Kay:

Q. 1. State your name, age, residence and occupation.
A. Andrew J. Cupples; I am 61; I reside in the 20th ward of the city of Pittsburgh; I am an engineer on the Pittsburgh fire department.
Q. 2. Have you any trade?
A. I am a machinery molder.
Q. 3. Did you ever work at the Fort Pitt foundry when it was operated by Knap, Rudd & Co., or Knap, Wade & Co.?
A. Yes, sir; I learned my trade there.
Q. 4. Please state about how long you worked there when it was operated by either of those two firms?
A. Most all the time from '50 or '51 up to '70.
Q. 5. Who was the foreman of that foundry when you worked there?
A. Joseph Kaye.
Q. 6. Were you any connection of his?
A. Son-in-law.
Q. 7. Did you have any knowledge while you were molder there of their casting cannon in those works?
A. Yes, sir.
Q. 8. Were those cannon cast solid or hollow?
A. Both.
Q. 9. What different sizes of cannon did they cast there?
A. From 8 up to 20 inches.
Q. 10. What kind of furnaces did they generally use for melting the metal for casting the cannon?
A. Air furnaces.
275 Q. 11. I believe those furnaces had a bed in which the metal was melted and the fire chamber at one end, and stack at the other, and that in melting down the pig metal the flame traveled over the metal on the hearth and that the molten metal was tapped out of the side of the furnace. Is this correct?
A. Yes, sir.
Q. 11½. How many furnaces did they use at one time for melting the metal in casting the cannon?
A. One, two and three furnaces, according to size.
Q. 12. When they used more than one furnace how did they carry the metal from the furnaces to the mold?
A. That wouldn't be right. If we only used one furnace we carried it the same as we did if we used three, that is carrying the iron to the gun. In making a gun from an 8-inch up we always cast in runners, we could not do it any other way at that time.
Q. 13. Did you ever cast more than one gun at the same time?

A. Yes, sir.

Q. 14. Will you please explain what those guns were, and how you happened to cast them at the same time?

A. We cast two 10-inch guns together to test the principle of the hollow and the solid guns.

Q. 15. How many furnaces did you employ for melting the metal in casting these two guns?

A. Three.

Q. 16. Will you please now describe the way in which the metal was taken from these three furnaces and introduced into the two gun molds?

A. Well, it was conducted by a runner from each furnace to a pool alongside of the guns, my recollection is about 20 inches high and 3 feet in diameter. The furnaces tapped into this pool and when we thought we had enough of metal in the pool we tapped it and conveyed it in two separate runners into these two guns.

276 Q. 17. Had you any object in taking the metal from the three furnaces into the pool before it was carried into the gun molds?

A. Well, we had two objects. One was to facilitate the casting of the gun, the other to try and get as near the same kind of iron in the guns.

Q. 18. Why did you want to get as near the same kind of iron in those two guns?

A. There was a great rivalry at that time between the hollow and the solid gun; in running the iron into this pool, we tried to get the same kind of iron out of these three furnaces in both guns.

Q. 19. Was either the solid gun or the hollow gun known by any particular name?

A. The hollow gun was the Rodman gun.

Q. 20. I would like you to explain somewhat more fully why you cast these two guns at the same time and tried to get the same kind of metal in them?

A. I could not explain that any more fully than I have.

Q. 21. Can you state what was done with these two guns after they were cast?

A. They was taken out and finished and proven.

Q. 22. What do you mean by "proven"?

A. Taken out to the proving ground, fired until they were bursted.

Q. 23. Had the question of getting the same kind of metal in those two runs anything to do with the proving of the two guns?

A. No, only we tried to get the same kind of iron in both guns.

Q. 24. You have described the pool into which the metal was conducted from the three furnaces as to its size; will you please now state at what points it was tapped?

A. When about two-thirds full.

Q. 25. I mean where were the tapping holes?

A. Right in the bottom.

277 Q. 26. You say the reservoir was about 3 feet in diameter; do you mean 3 feet inside diameter or outside diameter?

A. Inside.

Q. 27. Of what was it built?

A. It was built of brick, loamed and dried.

Q. 28. About when were these two guns cast at the Fort Pitt foundry?

A. I think along in '55 or '56.

Q. 29. You say that one of the objects in taking the metal from the three furnaces into the pool was to get as near the same kind of iron in the guns. In what way did you expect to get the same kind of iron in the guns by the use of this pool?

A. Well, by tapping the three furnaces, running them into this pool, we got a small mixture of iron before it went into these guns.

Q. 30. About what was the weight of these two guns?

A. I think in the neighborhood of 24 tons in the rough, that is, the two guns weighed about 24 tons.

Q. 31. About when did they first cast a 20-inch gun at that foundry?

A. About 1862 or 1863. I am not positive as to this, it was after the war started.

Q. 32. Did you have anything to do with making the arrangements for the casting of this 20-inch gun?

A. It was all made by my father-in-law and myself.

Q. 33. How many furnaces were employed in the casting of that 20-inch gun?

A. Three.

Q. 34. Please now describe the way in which the metal was taken from those three furnaces to the mold for that 20-inch gun.

A. Conveyed in runners to a pool and conveyed from the pool to the gun in runners.

278 Q. 35. About what was the size and construction of the pool which was then used?

A. My recollection—three feet in diameter, inside diameter; 20 inches high.

Q. 36. Where were the tapping holes for tapping out the metal from the pool?

A. Right in the bottom. When I say "bottom" I mean through the side of the brick work into the bottom of the pool.

Q. 37. How was this pool built up?

A. Of brick, loamed and dried.

Q. 38. Then it was of the same construction as the one used in the casting of the two guns of which you have testified?

A. Yes, sir.

Q. 39. In casting this 20-inch gun, how full did you run the pool before you tapped it?

A. About two-thirds.

Q. 40. How many runners did you have leading from the pool to the gun mold?

A. Two.

Q. 41. Where was the gun mold placed for casting?

A. In a pit underground.

Q. 42. Then I would understand that the metal from the three

furnaces ran into this pool and were mixed there, and then passed out through these two runners to the gun mold. Is that correct?

Question objected to, because the court can draw the correct inference from the testimony as well as the counsel, and the result of questions such as this is to put the counsel's reply in the mouth of the witness.

A. To a certain extent it was mixed there.

Q. 43. Do you remember about how many tons of metal were employed in casting this 20-inch gun?

A. Eighty some ton, I don't remember exactly.

279 Q. 44. Can you identify drawings showing generally the way in which this 20-inch gun was cast?

A. Yes, that is pretty near the thing; that is the whole principle of casting the 20 inch gun.

Q. 45. Please look again at the drawing and state whether it substantially shows the plan of the furnaces, runners, pool, mold and pit, such as you have described in your testimony as employed in the casting of that 20-inch gun.

Objected to as grossly leading, because the witness is not shown to have made the drawing, nor to have directed the making of it in any way.

A. According to my recollection it is.

(The drawing referred to by the witness is offered in evidence and marked "Defendant's Exhibit Plan Casting 20-inch Gun.")

Q. 46. How many of these 20-inch guns were cast in that foundry?

A. I think three.

Q. 47. Did the way that the metal was taken from the furnaces to the mold in forming the other two guns differ from that you have described in connection with the first one?

A. I think about the same.

Q. 48. When this first 20-inch gun was cast did it attract attention outside of the persons directly connected with the Fort Pitt foundry?

A. It did.

Q. 49. Do you remember whether any persons were present at the time it was cast who were not connected with the foundry?

A. Yes, sir. Mr. Rodman, the patentee of the gun; and different army officers, reporters, and a great many citizens.

Q. 50. Do you remember whether any report of the casting of the gun was published in any way?

280 A. According to my recollection, the daily press gave a full account of it.

Q. 51. Did you read the reports of it in the daily papers at that time?

A. It is natural to suppose that I did, for I was directly interested in it.

Q. 52. I hand you a report of the casting of that gun taken from the Pittsburgh Daily Commercial of Friday, Feb. 12, 1864. Please

read it over and state whether that was about the report published in the daily papers at that time?

Objected to, inasmuch as the paper itself, if in evidence, would not be competent under the provisions of the United States statutes in regard to patents, it not being a printed publication within the meaning of those statutes.

A. That is about correct as far as I know about it.

Q. 53. How nearly correct is the description given in this article of the way in which the mold was prepared and the gun was cast?

A. It is about correct.

The above newspaper article from the Pittsburgh Daily Commercial, Friday, Feb. 12, 1864, is here offered in evidence and marked "Defendant's Exhibit Pittsburgh Commercial Article." Defendant's counsel states on the record that further proof of the publication of the article will be furnished.

Objected to by counsel for complainant because the typewritten paper now offered in evidence is utterly incompetent as proof of the publication of the article, the date of publication, the completeness of the copy and, further, because even if all these matters were proved, it would not be competent as a prior printed publication to invalidate a United States patent.

281 Q. 54. I believe I forgot to ask as to what kind of metal was melted in these air furnaces and subsequently passed through the pool in making the castings of which you have testified. Please answer this?

A. In the first place this metal is taken from the pig, melted, run in a pig bed, and cast, remelted before it goes into the gun. It is originally pig metal, and is melted twice before it goes into the gun.

Q. 55. When you were at the Fort Pitt foundry did you have any knowledge there of their casting shot and shell?

A. Yes, sir.

Q. 56. Please describe the custom in those works in melting the metal for casting the shot and shell, and taking it to the molds?

A. In making shot or shell the pig metal is always as a general thing melted in a cupola. After it is started to melt we tap it into a shank, and then it is put into a smaller shank and carried to the molds and cast.

Q. 57. About what is the size of this shank into which the metal is run from the cupola?

A. It will hold about 500 pounds.

Q. 58. Do you let the metal run continuously into the shank from the cupola, or do you stop off the metal? What was your custom in regard to this?

A. As long as we could carry it away and use it in casting, we let it run. If we couldn't take it away fast enough, we either shut down the fan which stopped the melting or else stopped the cupola in.

Q. 59. About what size were the small shanks you used?

A. From 100 to 250 pounds capacity.

Q. 60. How customary was this practice during the time you worked in the Fort Pitt foundry?

A. All the time.

Cross-examination by counsel for complainant:

X Q. 61. What practical knowledge or experience have you had in relation to the Bessemer direct-process practice?

282 A. I have had no experience in the Bessemer practice.

Counsel for complainant objects to this entire deposition, for the reason that it is not offered to disclose anything but instances of the well-known foundry practice, and has no relevancy whatsoever to the invention described in the patent in suit, and hence, it is considered unnecessary to further cross-examine the witness.

Defendant's counsel suggests that the relevancy of the evidence is a question for the court to determine.

ANDREW J. CUPPLES.

Testimony of Alexander Frew.

ALEXANDER FREW, a witness called on the part of the defendant, and being first duly sworn, deposes as follows in answer to questions put to him by Mr. Kay:

Q. 1. State your name, age, residence and occupation?

A. Alexander Frew, I am 53; Ingram Station, Allegheny county; machinist by trade.

Q. 2. Did you ever work at the Fort Pitt foundry when it was operated by Knap, Rudd & Co. or Knap, Wade & Co.?

A. Yes, sir; I learned my trade there.

Q. 3. About when did you start to work there, and how long did you continue to work there?

A. I think it was about 1856 that I started to work there; I served my apprenticeship there for four years, and I worked off and on there for three or four years. Until the war broke out, and then I worked there until the end of the rebellion.

Q. 4. Do you remember the casting of what was known as the 20-inch gun in the foundry of those works?

A. Yes, sir.

Q. 5. Did you personally do any work on that gun?

A. I superintended the turning of the gun.

Q. 6. Did you see the gun cast?

283 A. Yes, sir.

Q. 7. Please describe the way in which that casting was made?

A. There were three furnaces tapped at one time and conductors run from each furnace into a retort where the metal all run into that retort, and then run from that retort into the mold for casting the gun.

Q. 8. Whereabouts was the tap through which the metal ran from this retort into the mold?

A. It was tapped at the bottom of this tank. I suppose it was four or five feet to the mold.

Q. 9. About how large was this retort or tank?

A. About five feet in diameter, and about a couple of feet deep.

Q. 10. During the casting of the gun how full was this tank of metal?

A. I suppose it was about three-quarters full all the time.

Q. 11. Did you understand what the purpose was of using that tank between the furnaces and the molds?

A. It was to mix the different metals together from the different furnaces.

Q. 12. Did you understand why they wanted to mix the metals?

A. So as to be all uniform together.

Q. 13. What kind of furnaces were these that they used to melt the metal?

A. They were common air furnaces, just the same as a heating furnace.

Q. 14. Did you understand as to whether these furnaces all produced the same quality of metal?

A. I don't know how that was, the metal wouldn't be the same from each furnace, one furnace might be hotter than the other or colder than the other, which would make a difference in the metal.

284 Q. 15. When the gun was cast were there any persons present that were not connected with the foundry or works?

A. Yes, sir.

Q. 16. Do you remember any persons who were present then?

A. Mr. Rodman was there and some of the U. S. officers. I don't know who the balance were, as I did not know them.

Q. 17. Who was Mr. Rodman?

A. He was the patentee of this gun.

Q. 18. Do you remember whether an account was published in the newspapers of the casting of this gun?

A. Yes, sir.

Q. 19. Did you read any of the accounts that were published at that time?

A. Yes, sir.

Q. 20. I show you copy of the report of the casting of that gun, taken from "the Pittsburgh Daily Commercial" of Friday, Feb. 12, 1864. Please read it over and state whether that is about the report published in the daily papers at that time?

A. That is about the correct thing.

Q. 21. How nearly correct is the description given in this article of the way in which the mold was prepared and the gun was cast?

This method of examining the witness is objected to for the reason that the witness is not stating to what he saw from his own recollection of it, but from recollection refreshed by reading a paper presented to him by counsel for defendant.

Defendant's counsel answers that the witness has been examined

as to his recollection of the entire matter, and that the question is simply put to him after he has testified as to his own recollection in order to ascertain whether the report given in the newspaper article is correct.

285 Further objection is made that it does not appear that the witness already testified how the mold was prepared or the gun was cast, and the paper now presented to the witness is evidently intended to refresh a defective memory.

Whether the witness' memory is defective can easily be seen by the court from an examination of the testimony.

A. It is correct.

Adjourned to meet same place tomorrow morning at 10.30.

Met pursuant to adjournment.
Present: Counsel as before.

Q. 22. Can you identify a drawing showing generally the plan of the furnaces, tank and mold with connecting runners, such as were employed in casting that 20-inch gun at the Fort Pitt foundry?

Objected to unless the witness can state that he made the drawing himself, or that it was made under inspection, or that he personally knows the correctness of it.

A. Yes, sir.

Q. 23. Please do so.

A. This drawing here—this appears to me to be correct; but the furnaces stood the other way, as I recollect it. My recollection is that their length was at right angles from the way they are shown in the drawing, and my recollection is that the middle furnace was tapped at the end.

It is noted on the record that the drawing referred to by the witness is marked "Defendant's Exhibit Plan Casting 20-inch Gun."

(Here follows diagram marked p. 285*a*.)

Q. 24. Please point out on this drawing the part you referred to in your testimony as the tank or retort, and state what it is marked on the drawing?

A. This is the retort here where the metal all ran into, into this pool. It is marked "pool" in the drawing.

286 Q. 25. And I understand that the metal ran from the three furnaces by runners into this pool?

A. Yes, sir.

Cross-examination by counsel for complainant:

X Q. 26. How old were you when you saw this casting of the gun at the Fort Pitt foundry?

A. I was about 23 years old, I think.

X Q. 27. Under whose direction were the arrangements made you have described for casting this gun?

United States Circuit Court – Western District of Pennsylvania.

Carnegie Steel Co. Limited

-vs-

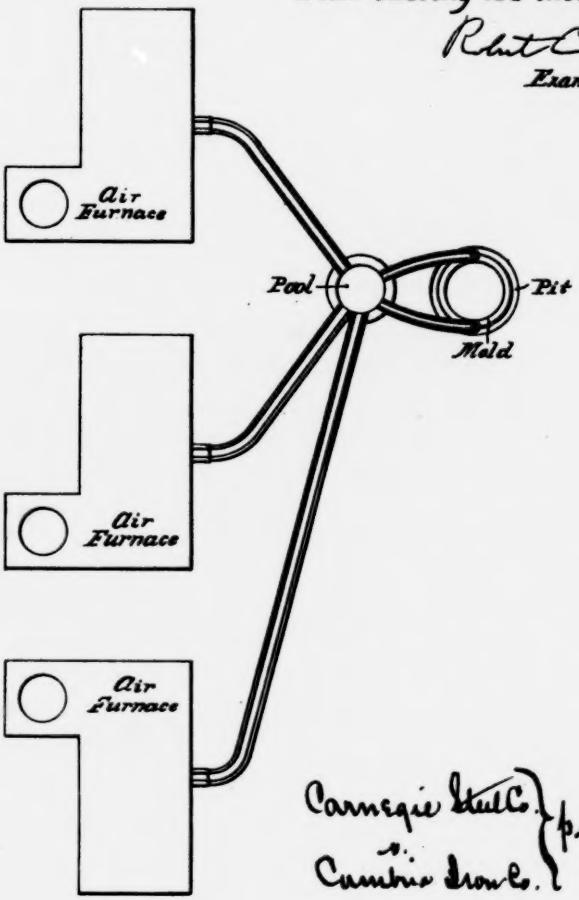
Cambria Iron Co.

Defendants Exhibit

Plan Casting 20 inch Gun

Robt C Totten

Examiner



Carnegie Steel Co. } p. 285 a
Cambria Iron Co. }

A. Mr. Kaye was the foreman there—Joseph Kaye.

X Q. 28. What was the pool constructed of which you say was used in this casting?

A. Brick.

X Q. 29. Who built it?

A. I couldn't tell that.

X Q. 30. It was built for the purpose of this casting, was it not?

A. Yes, sir.

X Q. 31. The metal was melted in cupola furnaces, was it not?

A. No, sir.

X Q. 32. The furnaces were simply used for melting the metal, were they not?

A. Yes, they were what they call air furnaces.

X Q. 33. They were all charged at the same time, were they not?

A. I don't know, I didn't work in the foundry.

X Q. 34. Then much of your testimony in regard to this matter is derived from what you were told at the time and not all of it from your personal observation, is that so?

Objected to as indefinite, it being counsel's duty to point out any particular part of the testimony to which the question may apply rather than to make it sweeping as to the whole.

287 A. No, I seen the operation of the casting of the gun.

X Q. 35. How many such guns were cast at that foundry to your knowledge?

A. There were two 20-inch, one was called an army and the other a navy gun.

X Q. 36. What was the weight of each of these guns?

A. Well, I couldn't just tell you, 75 or 80 tons.

X Q. 37. What was the capacity for melted metal of each of these air furnaces?

A. Well, I couldn't answer that.

X Q. 38. Were they all run at the same time into the pool you have spoken of?

A. Yes, sir.

X Q. 39. You have given the dimensions of this pool; do you know that these dimensions are correct?

A. I couldn't say they were exact; as near as I recollect they are right.

X Q. 40. No one of these air furnaces contained sufficient metal for the whole gun, did they?

A. No, I don't think they did, because they used that many furnaces. They would not hold that much, I am satisfied.

X Q. 41. It was the purpose of using this pool and running the metal from the three furnaces into it before casting to have the metal all run into the mold at the same time, so as not to make any break or flaw in the casting, as might have been the case if the contents of each furnace were running separately into the mold; is not this so?

A. I suppose the pool was there for mixing these metals before they run into the mold.

X Q. 42. Please have my last question read to you and then state specifically whether you can say no to it?

A. I can say yes to your previous question.

X Q. 43. What did the charge of metal in each of the air furnaces consist of?

288 A. I couldn't answer that, I don't know anything about mixing the metals.

X Q. 44. Then you are not prepared to say that there was any difference between the metal in these three furnaces, are you?

A. No.

X Q. 45. The drawing which you have referred to in your direct examination this morning was not made by you, was it?

A. No, sir.

X Q. 46. At the length of time which has elapsed since the casting of the two guns you have referred to at the Fort Pitt foundry you are not prepared to swear positively as to the correctness of that drawing, are you?

A. No, I could not. It is as near as I can tell from what I remember.

X Q. 47. At the time when these guns were cast, what was your position in the works?

A. I was foreman of the turning mill and boring mill.

X Q. 48. Then you do not know much of what took place at the time of the casting of these guns, or of the reasons for what was done at that time, beyond what you saw as one of the numerous spectators of that casting?

A. That is all.

X Q. 49. These guns which were cast at that time were reputed to be the largest cast-iron guns that had ever been made, were they not?

A. Yes, sir.

X Q. 50. And therefore they involved the pouring of a larger quantity of molten metal into a mold than was at all usual previous to that time in foundry practice; was that not so?

A. Yes, sir.

X Q. 51. And it was these unusual circumstances which caused the presence of so many spectators, who are stated to have been there; is not that so?

289 A. Yes, sir.

X Q. 52. What acquaintance, if any, have you had with the direct process in Bessemer practice?

A. I have no acquaintance with it.

ALEX. FREW.

Testimony of Robert C. Totten.

ROBERT C. TOTTEN, a witness called on behalf of defendant, being first duly sworn, deposes and says in answer to questions put to him by Mr. Kay as follows:

Q. 1. State your name, age, residence and occupation.

A. Robert C. Totten; 63 years of age; Sewickley, Pa.; I am at present employed as clerk and notary public.

Q. 2. Were you ever engaged as a founder and machinist, and if so, during what period?

A. From 1863 to 1892, founder and machinist, Fulton foundry, Pittsburgh, under the firms, Pennock and Totten, and Totten & Co., as having entire charge of that establishment.

Q. 3. When so engaged were you acquainted with the foundry practice pursued in those works?

A. Yes, sir. I gave my personal attention to the purchase of all pig iron and as a rule, gave instructions to those who melted the iron as to the grades and qualities to be used in making castings.

Q. 4. In connection with your foundry practice in those works prior to 1885, and you can understand that your testimony is to relate to a period before that date, did you ever employ the molten metal from more than one furnace in connection with making a casting, and if so, what kind of castings was this practice employed with?

A. We used to melt the iron in both an air furnace and cupola furnace, and in making chilled rolls of large dimensions would employ both the air furnace and the cupola furnace, con-
290 ducting the metal from each into a common large ladle, say of 20-ton capacity. Then the chilled roll was poured from this 20-ton ladle.

Q. 5. Please state for what purposes you conducted the metal from both the air furnace and the cupola furnace into the common large ladle.

A. In the first place, to obtain sufficient quantity in one receptacle to pour the roll; second, to obtain homogeneous metal.

Q. 6. In what way did this enable you to obtain homogeneous metal?

A. It is a well-known fact in foundry practice that the metal from an air furnace will vary in quality according to the conditions of fuel and atmospheric temperature, and that if the same kind of metal was used in a cupola furnace as it trickled down through the beds of coke, it would become impregnated with the impurities of the fuel, such as sulphur, and that if you attempted to pour a roll directly from the air furnace and from the cupola furnace without carrying the melted iron into a common reservoir, some parts of your roll would be hard and some parts soft, and the purpose of conveying them into a common reservoir was to allow the intermingling of these melted products and to produce a uniform homogeneous mixture, which was an essential thing in the casting of a chilled roll.

Q. 7. Why is uniformity of metal a necessary element for successfully forming a chilled-iron roll?

A. The value of a chilled-iron roll depends according to the purpose for which it is to be used, upon the depth of the chill, and this depends upon the amount of carbon, silicon and manganese in the metal before it is melted, so that if these elements are changed in the process of melting, and that which was melted in an air furnace was taken into the mold, and that which was taken from the cupola furnace was taken separately into the mold, it would be impossible to say how much chill there was on different parts of the roll, as the process of melting interferes with this tendency to
291 chill, no matter how carefully and uniformly the pig iron when first put into the air furnace or into the cupola furnace is selected, the only practical way to obtain a uniform depth of chill is to be certain that these two bodies of iron have been thoroughly mingled in their molten condition before the roll is poured.

Q. 8. In answer 6, you refer to the metal in the cupola furnace becoming impregnated with the impurities of the fuel, such as sulphur. Are there any other impurities which it might take up, and have these impurities any effect upon the metal in its use for forming a roll, either as to chill or other part of the roll?

A. Where fluxes are used the metal might become impregnated with other impurities, but in my foundry practice I very seldom used any flux, and the principal enemy to the good qualities of chilled iron is sulphur, and this is the main difficulty in getting a good mixture for chilled rolls out of the cupola furnace, because sulphur destroys the elements which go to make a good chilled-roll mixture which I have referred to as carbon silicon and manganese.

Q. 9. During what period was it your custom at the Fulton foundry to employ the practice you have described in melting the pig metal for one large roll in two furnaces and mingling the metal in the large ladle before pouring?

A. I believe the first roll cast in this way was about 1866 and from that time on.

Q. 10. Did you, as your foundry practice before 1885, make small castings at the Fulton foundry from metal melted in the cupola?

A. Well, I should say, yes, sir, moderately small castings.

Q. 11. Please describe the way in which the metal was handled from the cupola to the molds in making these small castings.

A. The product of the Fulton foundry was principally
292 rolling-mill castings and heavy machinery; the cupola furnaces principally used had a capacity of 10 to 20 tons each. The common practice was to place a ladle holding 3 to 4 thousand pounds at the cupola and allow the metal as it came from the bosh of the cupola furnace to run into this large ladle. From there it was emptied, or rather it was poured, into smaller shanks of various sizes and thus conveyed to the mold, while the ladle itself was not entirely emptied, as it was refilled from time to time by tapping out the melted iron from the bosh of the cupola furnace.

Q. 12. About what were the sizes of these smaller shanks into which the metal was poured from the large ladle?

A. They ranged in capacity from 100 pounds to 400.

Q. 13. How full was it your custom to keep the large ladle?

A. I should say on an average, about three-quarters full.

Q. 14. Had you any way of holding the heat of the metal which was poured into these large ladles so as to prevent the rapid chilling thereof when in the ladle?

A. It was a common practice to throw pulverized charcoal or coal dust on top of this melted iron in the large ladle, in order to retain the heat.

Q. 15. How did this charcoal or coal dust serve to retain the heat of the metal?

A. Well, my theory would be, that it excluded the air and was of a nature to increase the heat of the melted iron.

Q. 16. How effectually did it serve the purpose?

A. It certainly answered the purpose of preventing any chilling of the iron within a reasonable length of time.

Q. 17. I forgot to ask you, in connection with the casting of chilled rolls, as to how soon after you had mingled the metal of the two furnaces in the one large ladle, as you have described, you poured the mingled metal into the mold? Please answer this.

293 A. Chilled rolls cannot be poured with metal that is too hot, and it was sometimes as long as 15 to 20 minutes after the ladle was full that the roll was poured.

Q. 18. Was that delay for the purpose of simply cooling down the metal to the proper temperature or for permitting the metal to intermingle?

A. The primary purpose was to cool the metal, but it afforded undoubtedly a more perfect homogeneity.

Q. 19. What has been your experience as to the way in which metal coming from a cupola will vary in quality at different times in the same melt or run of the cupola?

A. I think it depends on the blast and the quality of fuel. Of course both these elements affecting some irons more than others according as to whether the pig iron put into the furnace was pure or impure itself. My own experience is that first-class charcoal irons will become deteriorated in passing through beds of impure fuel more than those irons which are not so absolutely pure in themselves.

Q. 20. Well, is there any variation from these causes or other causes in the quality of metal tapped from a cupola during the same melt or run?

A. I believe, as a rule, that there is great lack of uniformity, because even in the same car-load of coke there will be variations in the quality, and this will affect the result of the melting.

Q. 21. Well, in case the metal coming from the cupola was irregular in quality, would the tapping of the same at different times into the large ladle, as stated in your answer 11, have any affect upon it as to the uniformity of the metal?

A. It would certainly result in the intermingling of the various

tappings from the bosh of the cupola furnace, and result in homogeneity.

Cross-examination by counsel for complainant:

X Q. 22. Is there anything in what you described in your
294 testimony which differs in any material respects from what was a well-known foundry practice in casting chilled rolls at the time when you practiced what you have described?

A. So far as I have been able to discover by going around among other foundaries, my practice in this respect, so far as chilled rolls was concerned, was not common.

X Q. 23. In what respect did it differ from general foundry practice?

A. It arose out of the fact that I was the first one to make a very large chilled roll, and it required both the air furnace and the cupola furnace to do the work.

X Q. 24. Now tell us what the difference was.

A. I say that it arose from the exigencies of the case, but an essential part of the matter was to obtain a uniform quality of iron from the air furnace and the cupola furnace.

X Q. 25. Why would not the use of two cupola furnaces instead of an air furnace and a cupola furnace have met the difficulty?

A. I did not at that time have two cupola furnaces of sufficient capacity to make such a roll.

X Q. 26. And neither of the furnaces that you had was in itself sufficient to furnish the desired quantity of metal for a single roll, was it?

A. No; neither of them were sufficient.

X Q. 27. So that in case one of the furnaces yielded good metal and the other of the two furnaces yielded poor metal, you would obtain a result of a metal better than one and worse than the other?

A. Yes; the essential matter being homogeneity.

X Q. 28. You mean by that homogeneity of the metal throughout the one roll that you were casting?

A. Yes.

X Q. 29. This ladle which you have spoken of, how was it situate in regard to the furnaces?

295 A. It was placed near the mold which was to be poured. The iron was conducted from the air furnace in a runner into this ladle, the iron from the cupola was first brought down into a ladle and then conducted from that ladle by a runner into the large ladle.

X Q. 30. What was the comparative capacity of your large ladle and of the combined capacities of the two furnaces?

A. I aimed to melt as much as possible in the air furnace, and the remainder, if necessary, was brought from the cupola furnace; I should say about $\frac{3}{5}$ from the air furnace and $\frac{2}{5}$ from the cupola furnace.

X Q. 31. What quantity of metal was required for a single chilled roll of ordinary size?

A. Well, I don't know just what you mean by ordinary size.

X Q. 32. I mean the size ordinarily manufactured at your foundry.

A. An ordinary sheet roll would take about three tons of metal.

X Q. 33. What was the ladle you have spoken of constructed of?

A. Made of wrought iron, lined with loam on the inside.

X Q. 34. How continuously, if at all, was this large ladle used? That is to say, what interval was there usually between one use and the next one?

A. Sometimes longer, sometimes shorter; an average probably of eight to ten months.

ROBERT C. TOTTEN.

296 *Certificate.*

COUNTY OF ALLEGHENY, } ss:
State of Pennsylvania, }

I, G. I. Holdship, a notary public in and for said county, do hereby certify that Robert C. Totten, a witness for the defendant, was duly sworn by me, on the nineteenth of November, 1896, before giving his testimony in said case. I further certify that I am not connected by blood or marriage with any of the parties to said suit, nor interested in the event of the same.

In testimony whereof I have hereunto set my hand and affixed my notarial seal this 5th day of February, 1897.

G. I. HOLDSHIP,
Notary Public.

297 *Stipulation.*

Circuit Court of the United States.

THE CARNEGIE STEEL CO., LIMITED, }
vs. } District of Maryland.
MARYLAND STEEL CO. and FREDERICK W. WOOD, Receiver. }

THE CARNEGIE STEEL CO., LIMITED, } West. District of Penna.
vs. } No. —. May T., 1896.
CAMBRIA IRON CO. }

And now, to wit, Dec. 1st, 1896, it is hereby stipulated by and between the respective counsel in the above two entitled causes as follows, to wit:

That all testimony heretofore taken in either case shall be considered as in evidence in the other case;

That all testimony hereafter taken in either cause shall be entitled in both causes and shall be considered as in evidence in both causes;

That all exhibits including drawings and models heretofore or hereafter offered in evidence in either case, shall be entered as filed

in both cases, duplicates to be provided for one case or the other as found necessary;

That all defenses pleaded in the answer of the suit against the Cambria Iron Co., and the amendment thereto shall be considered as pleaded in the suit against the Maryland Steel Co. and Frederick W. Wood, receiver.

The records in both cases to be printed jointly.

JAMES K. BAKEWELL,
Counsel for The Carnegie Steel Co., Ltd., Complainant in Both Cases.
P. T. DODGE,
Counsel for Defendant Maryland Steel Co. and Fred. W. Woods, Rec'r.
JAMES I. KAY,
Counsel for Defendant Cambria Iron Co.

298 Depositions of witnesses and other evidence on the part of the defendant- in the above two causes, taken at the office of P. T. Dodge, Esq., Tribune building, New York, commencing on Thursday, December 10th, 1896, before John O. Goodenough, notary public and special examiner, by agreement of counsel, the depositions being taken at a time and place agreed upon by counsel.

Present: Wm. Bakewell, Esq., and J. K. Bakewell, Esq., on behalf of complainant; P. T. Dodge, Esq., and James I. Kay, Esq., on behalf of the defendants.

Defendants' counsel offers in evidence printed copies of the following U. S. patents:

No. 118,597 to Zoheth S. Durfee, dated August 29th, 1871, for methods of refining cast iron and making castings the same being marked "Exhibit 13, Durfee first patent."

No. 122,312, granted to Zoheth S. Durfee, dated January 2nd, 1872, for manufacture of iron and steel, the same being marked "Exhibit Durfee Second Patent."

No. 238,110 to W. Hainsworth, dated February 22d, 1881, for Bessemer plant and apparatus, the same being marked "Exhibit Hainsworth Patent."

No. 315,587, to J. P. Witherow, dated April 14, 1885, for manufacture of iron and steel, the same being marked "Exhibit Witherow First Patent."

No. 327,425, to J. P. Witherow, dated September 29, 1885, for steel-plant appliance, the same being marked "Exhibit Witherow Second Patent."

No. 51398, to H. Bessemer, dated December 5th, 1865, for making Bessemer steel, the same being marked "Exhibit Bessemer U. S. Patent."

No. 33446, to J. W. Nystrom, dated October 8th, 1861, for making Bessemer steel, the same being marked "Exhibit Nystrom Patent."

299 No. 55442, to Anton Lehage, dated June 5th, 1866, for the same being marked "Exhibit Lehage Patent."

No. 212,168, to R. M. Atwater, dated February 11, 1879, for manufacture of glass and furnace therefor, the same being marked "Exhibit Atwater Patent."

No. 120,005, to John Y. Smith, dated October 17, 1871, for the same being marked "Exhibit Smith Patent."

No. 96206, to S. Danks, dated October 26, 1869, for rotary puddling furnaces, the same being marked "Exhibit Danks Patent."

No. 124,224, to Wm. Sellers, dated March 5, 1872, for apparatus for puddling iron, the same being marked "Exhibit Sellers First Patent."

No. 172,508, to Wm. Sellers, dated January 18, 1876, for revolving puddlers, the same being marked "Exhibit Sellers Second Patent."

No. 159,712, to C. W. Siemens, dated February 9, 1875, for manufacture of iron and steel, the same being marked "Exhibit Siemens Patent."

No. 149,517, to C. Pernot, dated April 7, 1874, for mechanical puddlers, the same being marked "Exhibit Pernot First Patent."

No. 169,033, to C. Pernot, dated October 19, 1875, for inclined revolving puddling furnaces, the same being marked "Exhibit Pernot Second Patent."

Defendants' counsel also offers in evidence certified copies of the file-wrapper and contents in the matter of the application of the Jones patent in suit, No. 404,414, dated June 14th, 1889.

Also of the letters patent No. 404,415, to W. R. Jones, dated June 4th, 1889, for apparatus for mixing molten pig metal.

Defendants' counsel also offers in evidence blue-book printed copies of the following English patents:

No. 685 of 1872, granted to C. D. Abel, dated March 6th,
300 1872, being a communication from abroad by Zoheth S. Durfee, the same being marked "Exhibit No. 21, Abel-Durfee English patent."

No. 3672 of 1873, to Wm. Deighton, dated November 11th, 1873, the same being marked "Exhibit No. 22, Deighton English patent."

No. 2061 of 1856, to John L. Tabberner, dated September 4th, 1856, the same being marked "Exhibit No. 23, Tabberner English patent."

No. 44 of 1856 to Henry Bessemer, dated January 4th, 1856, the same being marked "Exhibit No. 24, Bessemer first English patent."

No. 566 of 1869 to Henry Bessemer, dated February 23d, 1869, the same being marked "Exhibit Bessemer Second English Patent."

No. 4920 of 1887 to Alfred Longsdon, dated December 27th, 1877, the same being marked "Exhibit Longsdon English Patent."

Defendants' counsel also offers in evidence the following copies of printed publications, the same being certified from the record of the United States Patent Office:

The following extracts from Kohn on Iron and Steel Manufacture, published in 1868, to wit:

On page 74, article entitled "The history of Bessemer process;" on pages 91 and 92, article entitled "The Barrow hematite steel works;" on page 95, article entitled "The Newberg iron and steel works;" on page 94, article entitled "Bessemer steel plant at Barrow."

The following extracts from the Journal of the Iron and Steel Institute, published in London, England, for certain years as follows, the actual publication being that year or the following year:

Year 1871, vol. 1, pages 400 to 416, article entitled "On the production of alloys of iron and manganese, and their application to the manufacture of steel, by Mr. F. Kohn."

301 Year 1874, vol. 1, pages 348 to 367 inclusive, article entitled "American rolling mills," by Mr. Alexander L. Holley.

Year 1875, pages 16 to 41, entitled "The President's address."

Year 1875, pages 125 to 127, article entitled "Manufacture of steel—Bessemer works," being part of an article entitled "Notes of a visit to coal and iron mines and iron works in the United States," by Mr. J. Lowthian Bell, F. R. S.

Year 1875, pages 194 to 219, article entitled "The manufacture of Bessemer steel in Belgium," by Mr. M. Julien Deby, C. E.

Year 1875, pages 344 to 349, article entitled "American Bessemer works and rolling-mill plant," being part of report on the progress of the iron and steel industries in foreign countries, by David Forbes, foreign secretary to the iron and steel industries.

Year 1876, on pages 12 and 42 inclusive, and on pages 420 to 427 inclusive, first article being entitled "The use of molten iron direct from the blast furnace for Bessemer purposes," and the second article being headed "Thursday, 21st of September, 1876," and being apparently the discussion on the preceding paper, the two forming one article.

Year 1878, pages 122 to 137, being a discussion on Mr. Holland's paper, which paper appears on page 104 of the same journal and is entitled "The manufacture of Bessemer steel and steel rails at the works of Messrs. Brown, Bailey & Dixon (Limited), Sheffield," by Mr. C. B. Holland.

The following extracts from "Engineering," published in London, England, for certain years, as follows:

Year 1874, vol. 18, page 310, on September 23d, 1874, a letter entitled "The Bessemer process," by Z. S. Durfee.

302 Year 1877, vol. 23, dated March 9th, 1877, pages 183 to 184, article entitled "American iron and steel works, No. 1," by A. L. Holley and Lenox Smith.

Year 1877, vol. 23, pages 357 to 360, May 11, 1877, article entitled "The Pennsylvania railroad, No. XIX, the Altoona shops" (continued).

Year 1878, vol. 25, page 295, April 19th, 1878, article entitled "American iron and steel works," by A. L. Holley and Lenox Smith.

Year 1880, vol. 30, pages 95 and 96, July 30th, 1880, article entitled "Barrow hematite iron and steel works."

Year 1873, vol. 15, pages 113 and 114, February 14th, 1873, article entitled "Bessemer machinery," by A. L. Holley.

Year 1872, vol. 14, pages 416 and 417, December 28th, 1872, article entitled "Bessemer machinery," by A. L. Holley.

Year 1875, vol. 20, page 147, August 20th, 1875, article entitled "The Edgar Thomson steel works."

Jean's History of Steel Manufactures, published in London, 1880, pages 421 to 425 inclusive, article entitled "The Rhymney steel works."

Stahl and Eisen, V. Jahrgang, published January, 1885, page 26, being a translation made by the official translator of U. S. Patent Office from the German of the article entitled "Small Bessemer works in connection with large Bessemer furnaces."

Transactions of the American Society of Mechanical Engineers for the years 1884 and 1885, published 1885, vol. 6, on pages 40 to 60 inclusive, an article entitled "An account of the experimental steel works at Wyandotte, Michigan," by W. F. Durfee.

In the same volume, pages 61 to 70 inclusive, an article entitled "The original Bessemer plant at Troy," by R. W. Hunt.

303 Transactions of the American Institute of Mining Engineers, for the years 1876 and 1877, published 1877, vol. 5, pages 201 to 216 inclusive, an article entitled "A history of the Bessemer manufacture in America" by R. W. Hunt.

Defendant's counsel also offer in evidence examined copies of the following extracts from publications, to wit:

"The Founding of Metals" by Edward Kirk, published in Sharon, Pa., in 1879, and on pages 14 to 20 thereof.

Notes on the construction of ordinance, No. 21, published in Washington, 1883; subject—fabrication of cannon in Russia, by Lieut. Michael Levitsky, and on pages 14 and 15 thereof.

Reports of experiments on the strength and other properties of metals for cannon, by officers of the Ordnance department, U. S. Army, published by authority of the Secretary of War at Philadelphia, Pa., by Henry Carey Baird, 1856, and on pages 169, 184 and 185.

Reports of experiments on the properties of metals for cannon and the qualities of cannon powder, with an account of the fabrication and trial of a 15-inch gun by Capt. T. J. Rodman, of the Ordnance department U. S. Army, published by the authority of the Secretary of War at Boston, Mass., by Charles H. Crosby, 1861, and on pages 5, 6, 7 and 8, with accompanying plate; and also on page 129.

It is stipulated by complainant's counsel that the several publications above offered in evidence may be considered as printed publications made in the respective years stated in connection with the offer of the same.

Complainant's counsel further stipulates that the article heretofore offered in evidence and marked "Defendant's Exhibit Pittsburgh Commercial Article" was printed and formed part of the

issue of the Pittsburgh Commercial on the 12th day of February, 1864, said paper being a daily newspaper circulated and sold in the city of Pittsburgh, Pa.

Defendant's counsel also offer in evidence a printed publication,
being a pamphlet entitled "No. 2, second series, The direct
304 use of blast furnace metal in the Bessemer process," by A. L.
Holley, published in New York, 1877; copyrighted by A. L. Holley in 1877, and so marked, the same being marked "Exhibit Holley, 1877, Report."

Adjourned to 10.30 Thursday morning, by agreement of counsel.

THURSDAY, *December 11th*, 1896—10.30 a. m.

Met pursuant to agreement.
Present, counsel as yesterday.

Testimony of William F. Durfee.

WILLIAM F. DURFEE, being duly sworn as a witness on behalf of defendant, doth depose and say, in answer to interrogatories proposed to him by Mr. Dodge, as follows, to wit:

Q. 1. State your name, age, residence and occupation.

A. William F. Durfee; I reside at West New Brighton, S. I., N. Y.; I am a civil and mechanical engineer; I am 63 years of age.

Q. 2. State briefly what experience you have had in practical engineering, and more particularly with reference to the manufacture of iron and steel.

A. Throughout my business life I have practiced as a civil and mechanical engineer. I have constructed a number of establishments for the manufacture of iron and steel, also some foundries and machine shops. Among the establishments for the manufacture of iron and steel was the experimental works at Wyandotte, Michigan, in which was made the first Bessemer steel produced in America. I have had practical charge of the manufacturing operations of several large iron and steel works.

I had charge of the Midvale steel works, near Philadelphia, Pa., and during my service in that works the steel for the first bridge
across the Mississippi, known as the Eades bridge, was made
305 under my direction. I designed and erected the iron works at Milwaukee, Wisconsin; I built the second mill at North Chicago, Illinois; I built and had charge of the practical operation of the steel works at Bridgeport, Conn., which works were the first works in America in which gas was exclusively used as a fuel. In 1855 I built the Gosnold rolling mills at New Bedford, Mass.; I remodeled the rolling mills at Wyandotte, Michigan, and introduced the three-high rolls in place of the old two-high method of rolling rails. I am a member of the American Institute of Mining Engineers and am one of the vice-presidents of the American Society of Mechanical Engineers.

Q. 3. Are you familiar with the general practice in the manufacture of Bessemer steel in the United States, prior to October, 1888?

A. I consider myself familiar with such practice. I have had occasion very frequently to visit establishments where Bessemer steel was manufactured in the United States, and am well acquainted with most of the leading engineers in charge of such establishments, and have taken pains to keep myself thoroughly in touch with the progress of the art of manufacturing Bessemer steel. That applies to the period prior to 1888.

Q. 4. Have you examined the complainants Jones' patent No. 404,414, and do you understand the alleged method therein described. I ask you this question as a mechanical and metallurgical engineer, and ask that you consider the patent as you would a like description for publication?

A. I have examined the patent mentioned in the question, and believe that I fully understand its object and purpose.

Q. 5. What do you understand to be the invention described in the Jones method patent in suit?

A. The patentee declares (lines 4 and 5), that he has "invented a new and useful improvement in methods of mixing molten
306 pig metal." After going on at some length (lines 20 to 58) to describe various impurities and irregularities and variations in "metal tapped from different blast furnaces," the patentee goes on to say (line 59, page 1), "For the purpose of avoiding the practical evils above stated, I use in the refining process a charge composed not merely of metal taken at one time from the smelting furnace, but a number of parts, taken from different smelting furnaces, or from the same furnace at different casts, or at different periods of the same cast, and subject the metal before its final refining to a process of mixing, whereby its particles are diffused, or mingled thoroughly among each other, and the entire charge is practically homogeneous in composition, representing in each part the average of the unequally diffused and segregated elements of silicon and sulphur, originally in each of the several charges. By proceeding in this way, not only is each charge for the refining furnace or converter homogeneous in itself, but, as it represents an average of a variety of ununiform constituent parts, all the charges of the converter from time to time will be substantially uniform, and the products of all will be homogeneous.

"To this end my invention may be practiced with a variety of forms of apparatus; for example, by merely receiving in a charging ladle a number of small portions of metal taken from several ladles or receiving vessels, containing crude metal obtained at different times or from different furnaces, the mixing being performed merely by the act of pouring into the charging vessels, and other like means may be employed. Then again on line 100, page 1, the patentee states: "My invention is not limited to the use in connection with converters, since similar advantages may be obtained by casting the metal from the mixing vessel into pigs for use in converters, puddling furnaces, or for any other uses to which pig iron may be put in the art."

Then after describing his apparatus, in which this mixing is

effected, the patentee says (line 75, page 2): "Before introducing the first charge, however, the mixing vessel should
307 be heated by an internal combustion of coke or gas, and when the walls of the vessel are sufficiently hot to hold the molten metal without chilling it, it is charged repeatedly from the cars 7, with metal obtained either from a number of furnaces, or at different times from a single furnace. The charges of metal introduced at different times into the vessel, though differing in quality, mix together, and when the vessel has received a sufficient charge, its contents constitute a homogeneous molten mass, whose quality may not be precisely the same as that of any one of its constituent charges, but represents the average quality of all the charges. If desired, the commingling of the contents may be aided by agitation of the vessel on its trunnions, so as to cause the stirring or shaking of its liquid contents."

Then again on line 111, page 2, the patentee states: "If care is exercised, in keeping the cover closed, the metal can be kept in a fluid condition for a long time, the heat being kept up by repeated fresh charges of molten metal, and, if necessary or found desirable, by burning gas introduced by a pipe or pipes in its interior."

Then after speaking of the methods of discharging the metal from the mixing vessel, the inventor says (line 128, page 2): "The tilting of the vessel does not, however, drain off all the contents thereof, a portion being prevented from escaping by reason of the elevated position of the spout C, and as the vessel is replenished, from time to time, each new charge mixes with parts of previous charges remaining in the vessel, by which means any sudden variation in the quality of the metal supplied to the converter is avoided."

Then, after speaking of the advantage of employing two or more mixing vessels, the inventor states (line 14, p. 9): "My invention is, however, not limited to the employment of two or any specific number of such vessels."

308 Then after describing some other parts of the apparatus the inventor says (line 25, page 3): "There is also a hole (19) at the rear end of the vessel near the top, through which a rabble may be inserted for the purpose of assisting or accelerating the mixing of the molten metal."

The inventor claims, first: "In the art of refining iron directly from the smelting furnace the process of equalizing the chemical composition of the crude metal by thoroughly commingling or mixing together the liquid-metal charge and subsequently refining the mixed and equalized charge substantially as and for the purpose described. Second. In the art of mixing molten metal to secure uniformity of the same, in its constituent parts preparatory to further treatment, the process of introducing into a mixing receptacle successive portions of molten metal ununiform in their non-metallic constituents (sulphur, silicon, etc.) removing portions only of the composite molten contents of the receptacle, without entirely draining or emptying the same, and successively replenishing the receptacle with fresh ununiform additions, substantially as and for the purposes described."

From my study of this patent of Jones I am of the opinion that his invention consists in mixing a number of charges of molten cast-iron or pig metal, ununiform in quality, in a suitable vessel. The character of this vessel I do not understand as being a part of the invention. The mixture may be effected in a ladle or it may be effected in a closed vessel. The mixture may be facilitated by rocking or agitating the vessel, or it may be accomplished by simply pouring the successive charges into the receptacle employed, and the mixture may be aided or assisted by stirring with a rabble. I do not understand that the invention is confined to the use of this metal for any particular purpose after it is mixed. It may be run into pigs or made into castings, or it may be put into a converter or refiner. So long as the mixing of ununiform charges of
309 metal in a suitable vessel for that operation is accomplished, I understand that the purpose of the invention of Jones is attained.

Complainant's counsel objects to so much of the preceding answer as undertakes to interpret the patent in suit, as that is solely the province of the court. The objection, however, is made with the understanding that it is not intended to apply to the answer in so far as it merely undertakes to explain the view of the patent taken by this witness as an expert on which he may base his future testimony in relation thereto.

Q. 6. Is there anything in the Jones patent to indicate that the pig metal which he produces is to be used in any other than the ordinary manner in the Bessemer process?

A. I don't find anything.

Q. 7. The Jones patent describes the practice of his mixing invention in a charging ladle. State what the charging ladle is.

A. The charging ladle is a vessel open at the top made of boiler iron, lined with refractory material and is used to receive the metal which is charged from this charging ladle into a converter. The ladle is supposed to be sufficient in size to hold an entire charge of metal for the converter, in connection with which it is used. In some cases this charging ladle is a ladle that is furnished with a bail by which it can be hoisted by means of a crane or other apparatus, and then its contents can be poured by tilting the ladle, in its suspending bail, into the converter. In other cases the charging ladle is supported on trunnions by which it can be tilted, but it remains fixed in one place. The particular arrangement of the charging ladle as regards mobility is such as will suit it to the circumstances under which it is employed.

Q. 8. Say whether or not charging ladles such as you have described were in general use in the United States prior to 1888?

310 A. The first charging ladle of the kind described that I ever saw was used in the experimental Bessemer steel works at Wyandotte, Michigan, in 1864. I have frequently seen them employed since that period in the years intervening between 1864 and 1888, at different works.

Q. 9. In what particular, if any, does the molten pig iron produced by Jones differ in its general character from the molten pig iron used in previous years in the ordinary Bessemer process?

Objected to as *as* it is utterly indefinite and comparing things which the witness has not described and does not appear to have any reference to the process described and claimed in the present suit. And further, because the witness has not shown that he has any knowledge as to the character of the pig iron produced by the Jones process.

A. It is my belief that a pig iron suitable for conversion into steel could be produced by the process described by Jones, and I know that pig iron was produced long before the process described by Jones, that was also suitable for conversion to steel.

Q. 10. I fail to make my question clear. I wish to know whether or not the pig iron produced by the Jones process is anything more or less than ordinary iron, such as was generally used in the Bessemer process prior to 1888?

Objected to as leading, notwithstanding the "whether or not" at the beginning of the question.

A. It is my belief that long prior to the invention of Jones pig iron was used for conversion into steel, that was of quite as good quality and that made quite as good steel as any pig iron that would be likely to result from the employment of the process of Jones. The pig iron produced by the Jones process would consist of iron and carbon and more or less impurities intermingled therein. The pig iron produced before the invention of Jones consisted of practically the same ingredients as would result from the operation of his process.

311 The foregoing answer and the question which led to it, objected to as showing an utter want of conception on the part of the witness of the purpose, scope or result of the invention of the patent in suit.

Q. 11. State whether you have examined the various patents and printed publications offered in evidence by the defendant, and whether you find in them any disclosure of the invention described in the Jones patent in suit. In your answer please state briefly the bearing of each publication to which you may refer, quoting from them such matters as are of special importance.

A. I have examined the patents and printed publications referred to in the question, and in some of them I find disclosed inventions which I believe to be identical in principle and operation with that described in the patent in suit; and in others there are points of construction and operation identical with some of the points of the patent in suit. I will first refer to the British patent to Wm. Deighton, dated November, 1873, No. 3672 of 1873.

On page 5 of this patent, line 8, the inventor states: "Instead of manufacturing Bessemer iron or steel from pig iron which has to be melted in cupolas, my invention also consists in taking the molten metal directly from the blast furnace to the converter, in which case

I prefer to arrange the Bessemer plant in a line at right angles to a row of two or more blast furnaces, and place a vessel to receive the molten metal tapped from two or more blast furnaces, to get a better average of metal, which will be more suitable for making Bessemer steel, or metal of uniform quality, the vessel or receiver being placed on a weighing machine, so that any required weight may be drawn or tapped from it and charged into the converter."

Line 34, page 6, the inventor says, "x^2, x^3 show the position of two smelting furnaces, Nos. 2 and 3, and two other furnaces are supposed to be in the same line, one by the side of No. 2 and
312 the other by the side of No. 3 furnace; y^1, y^2, y^3, y^4, are gates or channels for the molten metal from each furnace, which channels lead to a receiving vessel m, which is placed low enough to give fall to the molten metal to flow from the blast furnace to this receiver m, which forms a receptacle for mixing the molten metal from two or more of the smelting furnaces. From the receiver m the mixed molten metal is tapped and flows down the swivel trough n into the converter a. By placing the vessel m on a weighing machine, it can be readily ascertained when the exact quantity required has been tapped into the converter."

On line 35, page 7, the inventor Deighton claims: "Fifthly. The system or mode of arranging and working a Bessemer plant, in connection with one, two, or more blast or smelting furnaces, substantially as hereinbefore described and illustrated by figures 4 and 5 of the drawings.

"Sixthly. The system or mode of arranging and working Bessemer converters with a receiver or receptacle m for mixing the molten metal from two or more smelting furnaces, to get a more uniform quality of metal, substantially as hereinbefore described, and illustrated by the drawings."

In connection with this description I find illustrations, Fig. 1, Fig. 2, Fig. 4 and Fig. 5. In figure 4, which is a plan of a Bessemer plant arranged in accordance with the invention of Deighton, —. In this plan x^2 and x^3, represent two blast furnaces. From each of these furnaces, runners y^2 and y^3, extend to a receiving vessel m. These runners are intended to convey the metal from either or both of these blast furnaces to the vessel m. There are other runners provided, y^1 and y^4, which are intended to connect to other blast furnaces, placed to the right and left of those already named. Thus it will be possible in this plant of Deighton's, to mix in the vessel m iron from four blast furnaces. This mixed metal can be tapped from the vessel m into the converter a by means of the runner n.
313 If the vessel m is placed upon a weighing machine, as proposed by the inventor Deighton, an indefinite amount of this mixed metal can be tapped into the converter.

In Fig. 5 is a vertical section of the Deighton plant on line c–d Fig. 4, and shows a casting ladle l, which takes the metal from the converter after it has been converted into steel. For the purpose of ascertaining the comparative amount of metal that it is possible to treat at one conversion relative to the amount of metal that it is possible to accumulate in the reservoir or receiver m, I have calcu-

lated as near as I possibly can the maximum capacity of the casting ladle *l* and the reservoir *m*, and I find that the casting ladle *l* may contain 8.47 gross tons and the receiving vessel *m* may contain 103 gross tons. I have made sketches representing what I believe to be the interior dimensions of the casting ladle *l* and the reservoir *m*.

In comparing this invention of Deighton with the patent in suit, I find that both Deighton's patent and Jones' patent contemplate a mixture of metal taken from the two or more furnaces; or a mixture of metals taken at different times from the same furnace. I find that this mixture in both cases is accomplished in a vessel that is capable of receiving a great deal more metal than is treated at any single conversion. I find that in the Deighton patent it is possible to stir the metal with a rabble. It is also possible to stir the metal in Jones' patent with a rabble.

I find that in Deighton's patent there is a provision by which an indefinite amount of metal can be withdrawn from the mixing vessel. In Jones's patent there is also a provision for withdrawing any desired amount of metal at pleasure.

I find that the object expressed in the Deighton patent is to get a more uniform quality of metal by the mixing.

I find that in the Jones's patent there is a similar object. And from my experience I am clearly of the opinion that with
314 the apparatus of Deighton the same results can be obtained in practice as can be obtained by the apparatus of Jones.

I find British patent No. 685, March 6, 1872, for the manufacture of Bessemer steel and iron, issued to Charles Denton Abel, as a communication from Zoheth Sherman Durfee of the city of New York, U. S. A. In this patent the inventor says, page 1, bottom line: "In the conversion of iron by the Bessemer process, considerable economy would be effected by converting the crude iron immediately after it is tapped from the smelting furnace, before it has lost its heat and humidity. The difficulty in adopting this mode of operation arises from the variable character of the metal, which, as it runs from the smelting furnace, is sometimes of a quality unfit for conversion. One part of the present invention relates to a process and apparatus whereby this difficulty may be overcome. Between the smelting furnace (whether a blast furnace or a cupola furnace) and the converting vessel is introduced a reverbatory mixing furnace, by preference a gas furnace, of any suitable known construction, into which the crude metal from the smelting furnace is run, and wherein it is mixed with pig iron of suitable qualities, or with iron or steel or metal-oids such as it may be desirable to alloy with the crude metal, fluxes being also supplied for giving the required fluidity and purity, and the usual tests as to quality being applied to the mixed metal. The metal thus treated is then run into the converting vessels of known construction, wherein it is subjected to the Bessemer process. By properly arranging the levels of the smelting furnace, the mixing furnace, and the converting vessels the metal may be run direct from the one into the other without the necessity for hoisting ladles. Also the metal supplied for alloy

in the mixing furnace may be poured or run into it in a liquid state from melting furnaces or cupolas situated near it.

After speaking further of the saving of fuel and wear and
315 tear of the furnaces that would be effected by converting the pig iron immediately it is tapped from the blast furnace in which it is made, the inventor goes on to say (page 4, line 3), "This plan has been and may still be practiced to a considerable extent, but it has been found that by reason of the irregular working of blast furnaces, and the consequent varying character and quality of the crude iron produced, it was always very difficult and in most cases impossible to secure such uniformity in the converted metal as was essential to success in the business. Hence, at several establishments where the plan of taking the fluid iron as it was tapped from the blast furnace and pouring it at once into the converter has been practiced, it has been abandoned, the proprietors preferring to incur the expense of handling and remelting the crude iron after it had been cast into pigs, in order thus to secure the advantage of carefully selecting and mixing the materials, for each charge to be converted.

Now in order to secure the greater portion of the saving due to taking the iron from the blast furnace to the converter, without its being allowed to cool and solidify, and at the same time to obviate the disadvantages resulting from the variations in the character and quality of the blast-furnace product, and in order also to be able to mix irons to any desired extent I propose to place at any suitable points near the converting vessels, and by preference at such heights as will permit the metal to run into the converters from them without previously hoisting the ladles into which the metal may first be tapped, reverbatory furnaces, by preference gas furnaces, into which furnaces the crude iron as it is brought from the blast furnaces may be poured, and wherein it may be mixed with other irons, and be so treated as to insure the metal from time to time tapped out for conversion, being as nearly as practicable of a uniform character. So many and so large furnaces may be used as the work in progress may demand; but in many cases one furnace about double
316 the capacity of the converter in use will be sufficient, as the necessary correction of the character of the crude iron can be very quickly made. Gas furnaces offer especial advantages for this purpose, as they use much less fuel in maintaining a given temperature, than do the ordinary reverbatory furnaces, and can readily produce the highest heat required."

On page 5, line 4, the inventor says: "Some qualities or grades of crude iron cannot advantageously be used in the Bessemer process, because they do not contain sufficient quantities of heat-giving elements, such as carbon and silicon, and consequently work cold, and the steel produced from them chills so quickly that it cannot be tapped from the ladle. Now in the use of gas furnaces as herein proposed, such metals can be so highly heated before they shall be poured into the converter that the lack of heat-giving elements will be compensated, and as iron lacking such elements, chiefly the higher numbers of pig iron, is sold at lower prices than those irons

which contain them; reverberatory furnaces may also in many cases be advantageously used when iron is to be remelted for conversion; and when in such cases it may be cheapest to use cupola furnaces for melting pigs, I will place a reverberatory furnace at some convenient point between the cupola furnaces and converters and tap the iron from the cupolas into the reverberatory furnaces, and from thence, after first giving it the desired character in temperature, into the converter.

It will be understood that these reverberatory furnaces will give all needed opportunity for testing the irons under treatment, and also superior facilities for remelting any ingots and scrap which require to be reconverted."

On page 7 the inventor claims, line 23—

"1. Combining converting vessels with reverberatory furnaces and blast or smelting furnaces in such wise as that crude iron can be tapped and run or carried, raised and poured from the blast furnaces into the reverberatory furnaces, and then, after being
317 treated as may be desired, be tapped out and run into converters, substantially as and for the purposes described and specified.

"2. Combining converting vessels with reverberatory furnaces and cupola furnaces, in such wise as that the metal melted in the cupola furnaces can be run from thence into the reverberatory furnaces, and from the latter to the converters, substantially as and for the purposes described and specified.

"3. The herein-described modes of producing uniformity in the character of the iron to be converted by the pneumatic or Bessemer process."

In comparing this patent of Abel Durfee with the invention of Jones in the patent in suit I find that Durfee understood as fully as Jones appears to have done the irregular working of the blast furnaces, and a lack of continuous uniformity in the metal which they furnished for conversion. Durfee proposes to secure uniformity by mixing the metals produced in a reverberatory furnace, preferably a gas furnace, in which the metals can be mixed with other irons; that is to say, the metal from any blast furnace may be run into a reverberatory furnace and mixed with other iron taken from any source whatever; these other irons can be taken from a blast furnace in a liquid state, or from several blast furnaces; or they may be taken from one or more cupolas.

The size of this reverberatory furnace which Durfee employs may be such "as the work in progress may demand."

In Jones' invention he employs a vessel with a closed top, which is arched and performs precisely the same function in regard to the metal below it, as the roof of a reverberatory furnace. He has a provision in this vessel for heating it by coke or gas. When such a vessel as is described in the Jones patent is heated by gas, it is practically a gas-fired reverberatory furnace, and can be used in precisely the same way as the furnace contemplated by Durfee. In Jones' mixing vessel, there is opportunity provided for the ad

dition of any kind of iron or fluxes. In Durfee's reverbera-
318 tory furnace there is equal opportunity for adding any kind of iron or fluxes to the metal under treatment.

In Jones' receiving vessel there is opportunity for stirring the metal with a rabble. In Durfee's reverberatory furnace there will be equal opportunity for stirring the metal with a rabble.

In Jones' mixing vessel a definite quantity of the metal can be taken out for conversion at pleasure. From Durfee's reverberatory furnace a definite quantity of metal could be tapped for conversion whenever desired.

Jones and Durfee each seems to have had a clear idea of a proper means for correcting the irregular character of the metal produced by blast furnaces, and the apparatus devised by each is, for all practical purposes, identical in character. And I have no hesitation in saying that as good results would be obtained by the method described by Durfee as by the method described by Jones.

I will now quote from a letter by Z. S. Durfee published in "Engineering," a periodical published in London in 1874, vol. XVIII, page 310. In the second paragraph of this letter, page 1, it is stated that "Goransson, of Sweden, made the first successful conversion of metal taken from a blast furnace in 1858, I think, and this mode of conducting the Bessemer process is still practiced on a large scale in Sweden, and in Germany and Austria, where the iron is taken from small furnaces using pure and more or less manganese ores.

In the later attempts to carry on direct conversion of metal made in large furnaces with coke, and from the hematite and magnetic ores now so generally used, it was found that the varying character of the metal so produced made it difficult, if not generally impracticable, to make uniformly good steel; and further, it was impossible to arrange the tapping of the blast furnaces to coincide with the needs of the converters.

Hence steel-makers have generally preferred to incur the costs of running the crude metal into pigs, of handling and remelt-
319 ing it, with the consequent loss and waste, in order to have the opportunity of carefully selecting and mixing the pig irons for each charge to be converted.

To gain the greater part of the saving arising from converting the iron directly when it is tapped from the blast furnace, and to obviate the troubles arising from the variations in character of the product of the average blast furnaces, and also to be able to mix irons to any reasonable extent, I devised the following, as it seems to me, simple and practical plan.

I propose to erect at some convenient place as near as possible to the converter, one or more gas reverberatory furnaces of sufficient size to hold the average tap of the blast furnaces, supplying the metal for conversion, and then run or pour the crude metal from the blast furnaces into these gas furnaces, where it could be alloyed or treated as desired, and thence be tapped out from time to time as required by the converting operations.

It is well known that gas furnaces can hold molten iron in a fluid state for a considerable time with but little variation in its charac-

ter, and very small cost for fuel to maintain its heat, and it is manifest that while the metal is thus kept it can be easily alloyed and mixed at will.

On page 4, second paragraph from the top, Mr. Durfee says: "The quantity of iron now converted at once in Bessemer works is so large, that even after it has been tapped out into the ladle or run into the converter, it may be retained in a sufficiently hot and fluid state for the converting process for a long time, and I have known it to be so kept for several hours.

At least the metal can be so held as to permit it to be carried on a tramway as far as convenience would ever require, and thus the gas furnaces be located very much at will."

In the last paragraph on page 6, Mr. Durfee states: "The
320 arrangement for tapping the blast furnaces can be made so as to permit the molten iron to be run into ladles to be taken to the gas furnaces or into a pig bed as usual, so that if a furnace chances for the time being to be making graver or more silicious iron than is needed for immediate use, such iron can be cast into pigs and be saved for mixing with other irons when mixtures are needed at the gas furnaces.

In discussing the practicability of working the Bessemer process, with irons drawn more or less directly from the blast furnace, it must be understood that the ores used in the blast furnaces shall be naturally adapted for making suitable iron. There may be no insurmountable difficulty in so managing the charges and the working of the furnaces, as that with good ores a product of iron for the Bessemer process, meeting all its necessities can be made regularly and continuously, but I see no way in which the metal can be satisfactorily taken from large blast furnaces just when it is wanted for the conversions, and the use of a gas furnace intermediate between the blast furnace and the converter, will afford a better chance of correcting the injurious influence of phosphorus, sulphur and other impurities in irons, than we are likely to get otherwise.

In comparing the ideas and suggestions which I have quoted from this letter of Z. S. Durfee with the Jones patent in suit, I am clearly of the opinion that Durfee understood as perfectly as Jones the irregular action of the blast furnaces used for the production of iron for the making of steel by the Bessemer process. He understood fully, in my opinion, that by running the iron into a furnace fired with gas, he could alloy these irons in any way he saw fit to correct their irregular character and give them a uniformity such as is desirable for use in the Bessemer process. Jones also understood that by mixing irons in a closed vessel, that could be heated with gas, and which when so heated was practically a reverberatory gas furnace, that the irregular constitution of the iron would
321 be corrected by mixing in such furnace or vessel. Mr. Z. S. Durfee evidently understood the practical difficulty of tapping the furnaces at such times as would be convenient for the converters to receive the iron direct from them. He evidently saw the advantage of a large reservoir for collecting the iron from the blast furnaces, from which reservoir he could draw at any time, metal for

conversion. Jones also saw the advantage of a large reservoir for receiving and mixing the metal from two or more furnaces, and from which reservoir or mixing vessel he could draw charges for the converter at his convenience.

I am clearly of the opinion that the ideas and suggestions embodied in Mr. Durfee's letter cover practically the same ground and could be made to accomplish the same ends as the ideas and suggestions contained in the Jones patent in suit. I think a skilled metal-urgist would have no difficulty whatever in carrying into practice the ideas and suggestions proposed by Mr. Z. S. Durfee and producing by so doing, as good and in fact the same results as could possibly be accomplished by the means described in the patent in suit.

Adjourned by agreement of counsel till Saturday at 10 a. m.

SATURDAY MORNING, *December 12th*, 1896.

Met pursuant to adjournment.

Parties present as before.

Witness Durfee continues his answer to question 11:

I now refer to the United States patent granted to James B. Witherow, No. 327,425, dated Sept. 29, 1885. "For steel-plant appliances." On line 9, page 1, the inventor Witherow states: "In the manufacture of steel by the pneumatic process, the converters are charged with molten metal, the product of a blast furnace. This metal is usually cast in the form of pigs, and then remelted in a cupola as needed before being charged into a converter. The metal is usually cast from a blast furnace once in every six
322 hours, and the quantity thus cast is many times in excess of the charge of the converter. Economy of manufacture forbids more frequent casting, and particularly casting of the comparatively small quantity necessary for a converter charge, and with the frequency required therefor, the periods of the operations of which are comparatively much shorter than those of blast furnaces. It is very desirable to take advantage of the molten condition of the metal as it comes from the blast furnace for its use in the converter, because thereby the remelting of the metal and the expense of the construction of the cupola may be avoided. The charge of a converter is from one to five tons, and the cast of a blast furnace runs usually from ten to fifty tons. The difficulty of using the molten metal from the furnace in the converter consists in keeping the large quantity of metal from the latter in a proper molten condition for use in the former. The time between charges of the converter is usually twenty minutes and upwards, and the metal from the furnace must be kept in condition to be tapped from time to time into the converter as needed. This is the object of my invention."

Then after some description of the plans accompanying the patent, the inventor goes on to say (line 62, page 1):

"The receptacle *b*, is provided with a suitable cover *f*, and with tuyeres *g*, which blow down upon the surface of the metal for the

purpose of maintaining its heat and fluidity. I prefer to use hot or cold air or gas for this purpose. When natural gas is accessible, it may be used; but it should not be blown below the surface of the metal."

Then the inventor, line 77, page 1, continues: "The receptacle is also provided with a series of tapping holes *h*, arranged at different heights in its sides. The holes are preferably made in a vertical cast-iron stave *i*, and when the vessel is in use are stopped with clay. In tapping, the clay stopper of the proper hole is punctured, and the metal permitted to run out.

323 The tapping holes may be arranged as to relative heights with reference to the capacity of the vessel, so that the opening of any particular hole will insure the delivery of a determined quantity of metal. In this way the use of a weighing ladle or other means of determining the charge of the converter may be rendered unnecessary."

On line 103, page 1, the inventor says: "The amount and pressure of the blast in the tuyere or tuyeres will be regulated to suit the purpose for which it is supplied and the quantity of metal present."

The inventor claims as follows:

"1. The combination of a blast furnace with a storage receptacle provided with tuyeres for receiving and holding the fluid cast of the furnace, a distributing ladle, and conducting spouts for transferring the metal from one to another, substantially as and for the purposes described.

"2. A storage receptacle for containing and dispensing fluid metal provided with a tuyere or tuyeres for supplying a blast of air or gas to maintain the metal in a fluid condition and a suitable tapping hole, substantially as and for the purposes described.

"3. A storage receptacle for containing and dispensing fluid metal provided with a tuyere or tuyeres for supplying a blast of air or gas to maintain the temperature of the metal and a series of metal tapping holes arranged at different heights in the sides of the same, substantially as and for the purposes described."

To illustrate his invention, the inventor, Witherow, accompanies his patent with two sheets of drawings. In sheet 1, Fig. 1, is represented a vessel *b* provided with an arch top or cover *f*. This vessel is placed low enough with regard to the blast furnace A to admit of the metal running from the blast furnace through a gutter or channel D into it. There are tuyeres *g* represented for supplying air or gas to the interior of the vessel *b*. There is also a ladle *c* for receiving the metal which may be tapped into it from the

324 receiving vessel *b* through the spout *e*. This vessel *c* is intended to hold a charge for the converter.

In sheet 2 of the drawing accompanying this Witherow patent, the receiving vessel *b* is shown on a larger scale. In Fig 2, sheet 2, a series of tap-holes at different levels *h*, *h*, *h*, are represented.

In comparing this patent of Witherow with the patent in suit, it is evident to me that the inventor Witherow clearly recognized the practical difficulties of taking the metal directly from the blast fur-

nace to the converter and that he has provided means to overcome these difficulties in a way quite similar to that provided by Jones in the patent in suit.

Witherow provides a receiving vessel large enough to contain one or more tappings of a blast furnace. Jones's vessel is similar in capacity.

The inventor Witherow recognized tha desirability of tapping from this receiving vessel from time to time, charges of definite weight for use in the converter. Jones also has provided means for drawing from his receiving vessel charges of definite weight.

In Witherow's receiving vessel there is an arched roof which protects the metal from the cooling action of the external air. Jones's vessel has a similar arched roof, which is used for the same purpose.

In Witherow's vessel there is a provision for introducing gas above the surface of the metal. Jones also contemplates the possibility of introducing gas above the surface of the metal in his receiver.

If the gas introduced into either of these vessels is burned therein, the vessels each become practically gas furnaces.

The patentee Witherow clearly recognized the great economy resulting from taking the metal from the blast furnace and converting it into steel without allowing it to cool. Jones also recognized this advantage and economy.

325 After carefully comparing the inventions of Jones and Witherow, I am clearly of the opinion that by means of Witherow's apparatus an expert metal-urgist or practical steel-maker would, without difficulty, have been able to realize all the economies and advantages that are of practical value in the apparatus described in the patent in suit.

I now refer to the United States patent granted to James P. Witherow, No. 315,587, dated April 14, 1885, for apparatus for the manufacture of iron and steel. In the specifications of this patent, page 1, line 9, the inventor Witherow states:

"The object of my invention is to facilitate and cheapen the conversion of crude cast iron into ingot iron or steel by the Bessemer or pneumatic process. For this purpose I so combine the blast furnace in which the iron is produced or melted, with the converter and other appliances used by me, as to utilize the blast forcing and heating apparatus of the furnace for converting purposes, and make the production of steel from the ore a continuous operation in a single plant."

Then after describing at length his apparatus, the inventor Witherow goes on to say (line 65, page 1), "As, however, it is often undesirable to tap the metal from the blast furnace every time the converter, which is relatively very much smaller than the blast furnace, is charged, I have provided a vessel or receptable, E, having a tap-hole, *j*, capable of holding any desired quantity of metal. It is preferably constructed to take the full amount of a cast from the blast furnace, but may be made for or used with a smaller quantity."

Then after some further description of the apparatus the inventor says (line 98): "Thus the vessel E constitutes an intermediate distributing reservoir for the metal after its withdrawal from the blast furnace, the use of which obviates the necessity of interfering
326 with the regular and uniform operation of the blast furnace, by the frequent tapping off of the relatively small quantity of metal necessary to charge the converter or converters, the time required for the operation in the latter being so short that they need to be charged several times between each regular tapping of the blast furnace. The intermediate vessel E, may, if desired, be used in connection with a cupola, F, in which case its operation will be the same as has just been described."

The inventor, Witherow's first claim for his invention is as follows:

"1. The combination of a blast furnace, a blast heating stove, a converting vessel, an intermediate distributing receptacle, and connections for the blast and transfer of the metal, substantially as and for the purposes described."

In the drawings accompanying this patent, Witherow shows a blast furnace D provided with a gutter *k*, in which the metal can be run from it, either directly into the converter through an opening *f*; or it can be drawn off into a converting vessel E. This receiving vessel is mounted on the ram of a hydraulic lift, so that it can be raised or lowered. When it is desired to draw any of the metal from the receiving vessel, into the converter C, this vessel E is raised by means of the lift on which it is placed, into the position shown by the dotted lines in the drawing. The metal can then be tapped from it through the tap-hole *j*, into the gutter *k* and so run into the converter.

It is evident to me from the reading of the patent, that the vessel E was intended to contain a number of charges of the converter; and that the inventor contemplated the removal from the vessel E from time to time, such amounts of metal as were necessary for use in the converter, and also to tap the blast furnace whenever he desired.

From my knowledge of the state of the art, at the time this Witherow patent was granted, it is evident to me that the amount of metal removed from the vessel E for conversion would be
327 determined with sufficient accuracy in either of two ways. First, the vessel E may have rested upon the platform of a weighing scale by the use of which the loss of weight in the vessel E could be accurately weighed as the metal ran from the vessel into the gutter *k*; and when sufficient metal had been withdrawn for a conversion, the tap-hole *j* would be closed. Second, the weight removed from the vessel E would be determined very closely by noting the level of the surface as it flowed from the vessel.

The converter shown in the drawing is not of the tilted type but is immovably fixed in position.

In comparing this invention of Witherow's with the patent in suit, it is clear to me that he fully appreciated the economy resulting from the use of metal in the converter, taken directly from the

blast furnace, without allowing it to become cool. Jones also fully understood this.

Witherow also fully recognized the practical difficulty of tapping a blast furnace at short intervals, and drawing therefrom with sufficient precision the desired amount of metal for each conversion. Jones also understood this difficulty. To overcome this objection Witherow has provided a vessel in which a large amount of metal could be accumulated, equal to one tapping of the blast furnace at least, and from which accumulating vessel a requisite amount of metal could be withdrawn for each conversion. Jones also provided a vessel for accumulating metal, and from which he did withdraw from time to time, such amounts as he desired to use in his converter.

In the Witherow vessel it would be possible, if it was desired, to stir the metal by means of a rabble. In the patent in suit, Jones provides means by which the metal in his receiving vessel could be stirred by means of a rabble.

It is evident to me that in carrying out Witherow's invention, the size of the vessel E may be as large as desired; that it may take metal from a single furnace, or from several furnaces, without in any way interfering with its operation or changing the character of the invention and apparatus disclosed by Witherow.

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From my practical experience I have no hesitation in saying that the apparatus contemplated by Witherow could be made to work successfully, and that excellent practical results could be obtained by its use.

I now refer to a certified copy of an article entitled "The use of molten iron direct from the blast furnace for Bessemer purposes," contained in a publication entitled "The Journal of the Iron and Steel Institute," 1876, London.

In speaking on this subject, Mr. J. T. Smith, of Barrow, says: "The practical difficulty they had to encounter had really been very small, and he often wondered why they were so skeptical, and that they had not begun the direct process very much sooner; thus he felt somewhat ashamed that, instead of being among those who were the first to introduce that system, they had really been unduly cautious, and were simply following the lead of their friends abroad. So far as the quality of the steel was concerned, he ventured to express an opinion that the steel was better."

In discussing the subject Mr. Richards says: "They were putting the six blast furnaces in a row, the hearths being high enough to allow the molten metal to flow into a ladle, which would be mounted on a four-wheel carriage."

In discussing the subject Mr. Snelus said: "They had been working at the direct casting from the blast furnaces for some time. Like Mr. Smith, when they first started, they had a little trouble with their carriages, but for the previous two or three weeks they had been working continuously. He might state, to begin with, that they had only one pit at work, therefore they were limited as to the quantity they could make, and they had only three blast fur-

naces, the make of which was not very large. The previous week they used 450 tons pig iron direct, and the result, which he had carefully watched, gave them a yield of 83½ per cent. of ingots,
329 and 2¼ per cent. of scrap, including the ladle and sculls. * * * There was one point that had not been mentioned; with all the care that could be exercised at the blast furnace, he did think it was advisable to take the iron from one furnace, but they might get an average mixture by taking it from two. They found no difficulty in taking three tons from one furnace, stopping the furnace up again, and then going to another. * * * He might also state, in corroboration of what Mr. Smith had said, that the quality of the steel made direct from the blast furnace was certainly better than where the iron was melted in the cupola. They had just recently been making some steel boiler plates of a very high quality, and in no case had they any difficulty in making those plates with the iron direct from the blast furnaces, while such excellent results had they obtained, that in one case he had boiler plates stand 29 tons to the inch tensile strain, and stretch 35 per cent. before breaking, whereas they commonly stretched only about 20 per cent."

In discussing this subject Mr. Sharp said: "As a Bessemer steel maker of some years' standing, that being the principal manufacture in which they were engaged at the works he managed, he must say they had always considered it was desirable to use more brands of iron than one—that by using, say, an average of about four brands of iron they were much more successful in the results obtained than by using only one or two—they found that all the irons they bought varied very much in quality, and that, to his mind, had always been the great obstacle to running the metal direct from the blast furnace into the converter, particularly where they wished to have steel of a high and uniform quality; they had never yet met with one iron that they could go on working week by week, and month by month, without getting into trouble; and by using more brands than one they could, of course, get a much more uniform quality, and as one brand varied they threw a little out and put a little of another in, and so on. He thought
330 he was perfectly justified in stating that it was by having adopted that system and having given very careful attention to the quality of the materials they bought, that the steel manufactured at their works had acquired the reputation that it had done."

In discussing this subject, Mr. Bessemer said:

"He was exceedingly gratified to see that it was quite practical to work iron successfully by his process direct from the blast furnace; he had himself proposed the tapping of three furnaces into one ladle or receiver, and when he advised some of his friends, in a company with which he was connected in the neighborhood of Barrow, to go into steel-making they arranged their works some two years ago, so that the pig iron could be tapped into a ladle, or rather into a spherical vessel with an almost close top to it that would hold 20 tons. It was proposed to make at least three 7-ton tappings into

that vessel and to move it on wheels into the converting-house, using a pair of converting vessels, one after another, until the four charges of five tons each were worked off; having a second ladle or vessel on its journey to supply, so as to keep on working continuously and thus retain the heat, and form no scull at all in the ladle during transit, and, in fact, effect what had by very similar means, been done by those gentlemen who had just spoken, and which they appeared most successfully to have accomplished. He must, in conclusion, congratulate them very much on their success, and say also how exceedingly gratified he was to find that his earliest ideas had thus been brought into successful operation."

It is evident to me that at the time the discussion from which I have quoted occurred, in 1876, that there was a perfect knowledge widely diffused among metal-urgical engineers in England of the advantages and economies resulting from using metal for conversion taken directly from the blast furnace; and that it was well understood, in so doing, that it was better to mix the metal
331 of a number of furnaces, rather than to use metal taken from a single furnace. It was also evident that in carrying out this mixing the use of a large receiving vessel, which would hold a great number of charges for the converter, was well understood; that the taking of a single charge from time to time from this receiving vessel for conversion was well known. In so doing, of course, there was metal allowed to remain in the receiving vessel. It is also evident that the blast furnaces were tapped into this vessel whenever it was convenient, without regard to this fact of there being more or less metal remaining in the receiving vessel.

It was also evident that the tapping of metal from the blast furnaces was regarded as a method of mixing the products of these furnaces and securing an average metal for conversion.

It was also evident that the metal in the receiving vessels used at that time, could have been stirred and mixed with a rabble, if it were so desired.

It is also evident that the metal produced by the methods described was a very excellent one, "better," in fact, than metal taken for conversion from any single furnace, and better than steel produced from metal that had been remelted in the cupolas.

In comparing the practice described in the discussion from which I have quoted, with the invention disclosed in the patent in suit, I fail to see that the patentee Jones has produced any better results or adopted any substantially novel method for carrying out his alleged invention.

The metal produced for conversion by Jones was a mixture of metals taken from several blast furnaces, and represented an average quality of the product of those furnaces.

From the discussion already quoted, it is clear that in 1876 metal was used for conversion in England that was the product of a mixture of the metal of several blast furnaces, and was an average in quality of the metal produced by such furnaces.

332 Jones' metal was an average pig iron. The metal described as used in England in 1876 was an average pig iron.

I recognize no possibility of novelty in the quality of the metal produced by Jones, and I do not believe it possible, if the same ores were used in the blast furnace, to produce by the method disclosed by Jones, a metal for conversion that would be practically different from the metal produced for conversion by the methods described in the discussion from which I have quoted.

I now refer to a certified copy from the bound volumes of the library of the Patent Office, of pages 348 to 367 inclusive, and relative drawings, from the publication entitled "The Journal of the Iron and Steel Institute," London, 1874.

In this copy it is stated: "Mr. Edward Williams remarked that the quantity of steel produced by an American converter within a given time, appeared to be greatly in excess of the best makes he had ever known in this country; but he saw no reason to doubt the correctness of the figures." * * * "Mr. Williams thought there was a possible economy of greater value, viz: to take the fluid pig iron direct from the blast furnace to the converters, and so save the present costly, and, he believed, needless processes of casting into pigs and remelting. The cost of these was very considerable, and might, he was convinced, be altogether saved. Some of the continental makers had commenced this system, which was at that time, Mr. Williams believed, in successful operation. To remelt the pig iron in a cupola could not improve it, and probably made it worse; and at the works of Messrs. Bolckow, Vaughn & Co., it was proposed to try dealing with the fluid iron as described. So far as he could see, there was no reason to doubt the success of the operation; and he hoped to be able to report before long that it had succeeded." * * * "Mr. Williams was sorry to dissent from the confession of faith just made by Mr. Schneider. It was the good old orthodox belief, held for a long time firmly and
333 explicitly by most people in the trade; but of late doubt had been cast upon it, and a great many iron and steel makers, himself among the number, had almost given it up. In his opinion, it had this defect, that it was not true. He denied that iron was necessarily improved by mixing with other iron. * * * Care being given to the charging and management of blast furnaces, it was easy to say before the iron was tapped what it would be, and only on very rare occasions, of which the furnace would give sufficient notice, would it be necessary to set the iron aside as unfit to be used alone. In truth he (Mr. Williams) had, for three or four years, been making steel very successfully, many thousands of tons, from pig iron produced from a single blast furnace, which scarcely or never varied so as to make difficulty."

In discussing this subject, "Mr. E. Windsor Richards (of Ebbw Vale) said that, as regarded the question of making ingots, direct from the blast furnace, it had gone far beyond the experimental process. At the Terre Noire works, in the south of France, it was being done regularly; he had seen it in operation there himself. They had two blast furnaces placed nearly opposite the Bessemer works and tapped 1½ tons from one furnace and 1½ tons from the other, into a ladle, which was conveyed to the Bessemer converter,

and the fluid metal tipped in and blown in the ordinary manner, but it was very much better done at the works of Messrs. Petin-Gaudet, at Givors, near Lyons. This firm had two furnaces there, and the iron at that place, being of such a regular quality, there was not the slightest difficulty in making ingots of an even quality with metal direct from the blast furnace. The steel turned out at those works was well known, and bore a very high character for evenness of quality. He saw the process working about three years ago, and the operations were continued day and night. Further than that, the Belgians, at the works at Seraing, were so satisfied that this could be successfully done, that they were building new blast furnaces and putting up a Bessemer plant to work in
334 front of those furnaces, and to use the metal direct from them. He thought there was a very great deal of credit due the American gentlemen for the immense turnout of ingots that they showed. He did not think in England manufacturers, as a rule, did anything like it. He saw, in the paper read by Mr. Holley, that 125 tons per day (he supposed that was a day of 24 hours), were made from a pair of 5-ton converters."

In the same discussion, "Mr. Claridge wished to put it on record that running out the liquid metal into a puddling furnace had been done for more than 20 years, in South Staffordshire."

In the same discussion, "Mr. Snelus said he quite agreed with Mr. Williams that there was no insuperable difficulty in running the iron direct from the blast furnace into the converter" * * * "but the first essential was to get the metal sufficiently silicious to blow well, and by running it into a separate vessel, as they did in America, they could then deal with it as they liked. The plan in all the works in America was to melt in a cupola continuously, and then to run the iron into a ladle, which was balanced, and held from 10 to 12 tons. From the 6-ton charge was run direct into the converter. They wanted an intermediate vessel between the blast furnace and the converter and to insure regularity in steel rails."

Adjourned by agreement of counsel to Monday at 10.30 a. m.

MONDAY—10.30 a. m.

Met pursuant to agreement.
Present as before.

Witness Durfee continues:

In comparing the statements of this publication with the patent in suit, it is perfectly clear to me that the mixing of metal in a ladle or receiver was fully understood in Europe in 1874. The mixing practiced in Europe at that time was the same in idea, and in
335 fact in practice, as that disclosed by Jones in the patent in suit. Jones describes the mixing of molten metal as "being performed merely by the act of pouring into the charging ladle."

In the paper from which I have quoted, E. Windsor Richards describes the "tapping 1½ tons from one furnace; and 1½ tons from the other into a ladle which was conveyed to the Bessemer converter."

This description of Mr. Richards fully discloses a knowledge and practice of the art of mixing metals in the same way as that described by Jones.

In the discussion from which I have quoted, the statements of Mr. Snelus fully disclose the running of metal from cupolas into a ladle which held more than a single charge of the converter. He says, "They wanted an intermediate vessel between the blast furnace and converter."

It is evident to me, from the statements made in the paper from which I have quoted, that in Europe there was no doubt among experienced metal-urgists, in 1874, of the advantages of taking the metal for the manufacture of Bessemer steel direct from two or more blast furnaces, and of the mixing of the metal so taken, in a receiver or ladle before taking it to the converter for conversion into steel. And this, I understood to be the substance of the invention of Jones as disclosed in the patent in suit.

I now refer to an English patent granted to Henry Bessemer No. 566, and dated 23d of February, 1869.

In speaking of the arrangement of cupolas and apparatus used in carrying out his invention, the inventor says, (line 23, page 9), "In either case, in a line between the cupolas, but preferably nearer to the converting vessel, I mount a ladle or receiver B on a weighing machine C, with a short spout D, from each cupola, leading into it, so that the charge of iron to be converted is first run into the receiver B and weighed. * * *" (Line 24, page 9:) "By this arrangement each of the cupolas may be employed to supply
336 either of the converters, the exact quantity of metal employed being ascertained by weighing it in the receiver B before running it into the converter."

The inventor also states (page 10, line 35), "When two converting vessels are grouped as described I also employ two small cupola furnaces, *q*, *q*, for melting the magnesian and carburate of iron or spe*i*geleisen. These may be placed near a weighing ladle as shown, and the iron from them be run into the vessel or casting ladle, along the gutters before named, but I prefer to tap these small furnaces into a swing or travelling ladle, where the iron may be weighed, and be thus transferred to the converter or casting ladle, without being cooled or wasted by passing along the gutter."

In comparing this patent of Bessemer with the patent in suit, it is clear that the inventor understood perfectly in 1869, the advantage of an intermediate vessel between the cupolas or melting furnaces and the converter. He understood the mixing in such a vessel of metal taken from different furnaces; and this mixing of metal in a vessel intermediate between the cupola furnaces and the converter, I understand to be the invention disclosed by Jones.

I now refer to a publication called the Journal of the Iron and Steel Institute, published in 1875, in London, by E. & F. N. Spon, 48 Charing Cross. On page 344 of this publication I find the following statement in the description of the works of the Edgar Thomson Co., Ltd., situated at Braddock, 11 miles east of Pittsburgh, U. S.: "The converting appliances comprise three cupolas, each 40

feet high, 5 feet internal diameter; two 12-ton cupola ladles upon scales; two 5 ton converters, 15 feet high by 6 feet internal diameter; 12 crane ladles for casting, and a full supply of ingot molds and flasks for bottom casting."

From this description it is evident that there was in use in the United States at the works named, intermediate ladles between the cupola furnaces and converters; that in such ladles the metal was mixed in substantially the same way as was contemplated in the patent in suit.

337 I now refer to a certified copy of an extract from an article entitled "The manufacture of Bessemer steel and steel rails at the works of Messrs. Brown, Bayley & Dixon (Ltd), Sheffield," by Mr. C. B. Holland, contained in a publication entitled, "Journal of the Iron and Steel Institute," 1878, London.

In this paper Mr. Snelus says, "There were, no doubt, difficulties in the way of working iron direct from the blast furnace, and he was rather surprised at the statement Mr. Maynard had made as coming from Mr. Holley, because he had himself been in correspondence with Mr. Holley, who had informed him that at Bethlehem works Mr. Frith was doing half their work direct from the blast furnace, and had for some time had under consideration the idea of a receiving ladle, so as to receive the metal from the blast furnace, and hold it in readiness there for the converters. One great drawback to the direct casting process was that you could not always get your metal at the exact time you wanted it. He believed it would be found that the great advantage the Bessemer works in America had was the intermediate receiving ladle, which was designed by Mr. Holley, and which was universally used there, although it was never used in England. The Moss Bay Company attempted to modify the thing some time ago, and put up a heating furnace, but that, to his mind, was a step in the wrong direction. Anyhow, the thing had failed, and no one in England, as far as he knew, was using any intermediate receiver between the blast furnaces and the converters. He thought himself that the receiver was of considerable importance, both for saving time and for facilitating the admixture of iron; and he was confirmed in that view by the idea of Mr. Frith of Bethlehem, who was about putting up a thirty-ton ladle, according to Mr. Holley, to receive the metal from the blast furnace, and hold it in readiness, so that at a moment's notice you could take your iron into the converter and also obtain a better mixture."

338 From the foregoing statement of Mr. Snelus, it is evident that the use of an intermediate receiver between the blast furnaces and converters, was well understood in America in 1878; that such receivers held many times the charge of a converter, and that they were used for the mixing of irons from different furnaces, or the mixing of successive tappings from a single furnace. I believe that such mixing was substantially the same as that contemplated and disclosed in the patent in suit.

I now refer to the certified copy of an article entitled, "American iron and steel works, No. 1," by A. L. Holley and Lenox Smith,

contained in a publication entitled, "Engineering," Colburn, vol. XXIII, London, 1877.

In this article it is stated, "No American works is as yet using fluid iron direct from the blast furnace, although the Vulcan plant is arranged, and the others may readily be modified to do so." * * * "But in case the metal for conversion comes directly from blast furnaces, the conveniences thus provided for the spiegel furnaces and for the vessels do not in the least interfere with the convenient handling of the blast-furnace metal; on the contrary, this arrangement enables the convenient use of this metal in part, and of cupola metal in part, as may be made necessary by the insufficiency of smelting plant or by the irregularity of blast-furnace iron. If the intention is to use chiefly blast-furnace iron direct, the judicious use of a cupola (lined to a less diameter so as to run economically on a small product), enables the manager to mix and temper his irons, much sooner than he could so do by the blast furnace alone, and so to get a uniform steel."

The description speaks of two cupolo ladles mounted on trunnions and provided with tipping gear. Between these two ladles there is a blast-furnace ladle. There *is* gutters provided for taking the metal from either or both the cupolas into a single receiving
339 ladle, and also for taking the metal from either or both cupolas into the blast-furnace ladle, in which it is mixed with metal from the blast furnace.

The arrangement for mixing metal in ladles intermediate between cupolas and the blast furnace, and the converter, is very thoroughly worked out; so that any mixture of cupola metal from different cupolas and blast-furnace metal and cupola metal, can be made that is desired.

The article further states: "The cupola ladles *f*, *f*, facilitate the distribution of metal to the vessels. They form reservoirs which make the melting department and the converting department independent of each other, within limits. This advantage was not fully appreciated until the large productions of the last few years were attempted. Should any delay occur in casting, in preparing a vessel, or from any cause, the melting department keeps right on, for these three ladles will hold six-vessel charges, which may be stored and converted when the converting department is ready for them. Cast iron will 'live' in these thickly lined ladles, when covered with charcoal for several hours."

From the quotations which I have given from this paper it is evident to me that prior to this publication (in 1877) the placing of receiving vessels between cupolas and the converter and between the blast furnace and the converter, and the mixing of metals in these receivers, taken from blast furnace or from cupolas, or from both, was well understood. And I am clearly of the opinion that such mixing produced substantially the same practical results as that described by Jones in the patent in suit. The mixing described by Jones produced an average quality of molten pig metal. The mixing referred to in the paper from which I have quoted would also produce an average quality of molten pig metal.

I see nothing in the method of mixing described by Jones that would produce any different result practically, from the mixing of metals in the intermediate vessels or receivers described in the paper from which I have quoted.

340 I now refer to a publication entitled "The Direct Use of Blast-furnace Metal in the Bessemer Process, No. 2, Second Series" published in New York by A. L. Holley in 1877.

In this paper, Mr. Holley states: "It has not yet been practicable to work the blast furnace with sufficient regularity to realize approximately the theoretical advantages of the direct process." * * * "Fourth. The obvious remedy is to mix a number of blast-furnace charges, so as to reduce the irregularity to a minimum. Two systems of doing this are on the eve of trial; the one is simply mixing so few charges in a tank that the metal will be drawn out before it chills; the other is to store a large number of charges in a heated tank—that is to say, in an immense open-hearth furnace. A few words of history may be of interest. Mr. Bessemer's early intention was to use blast-furnace metal direct. The earlier Bessemer practice, especially in Sweden, was with metal right from the blast furnace."

In speaking of the practice at the West Cumberland works, Mr. Holley says: "The blast-furnace ladle and car are run upon a lift about 30 feet from the vessels, raised, and turned half around; then the ladle is tipped into a runner. There is a little more runner scrap than from cupola metal. As there are not blast furnaces enough to supply both pits, the cupolas of this 'A' pit are run as before, and an occasional ladle of blast-furnace metal is got besides." * * * "A vessel charge is tapped into a ladle from two furnaces always, and sometimes from three. The greater part of the charge is taken from the furnace which is making the most suitable metal, or, if one furnace is working hot and another cold, the manager draws the best mixture he can, due regard being paid to the proper relief and working of the furnaces." * * * * "In order to get a more uniform metal, Mr. Snelus is about trying the experiment of placing a 20-ton ladle on a hydraulic

341 lift at the 'A' pit, so arranged as to store, mix and pour say, three 6-ton to 7-ton blast-furnace taps, or to mix blast-furnace and cupola metal." * * * "The conditions which Mr. Snelus proposed to himself, when he set out to use direct metal, he thus stated at the Iron and Steel Institute discussion before mentioned: 1st. To construct a ladle and carriage that could be moved about with safety and celerity without being of an undue weight; that the ladle should be placed in the most secure position upon its carriage; that it should be easily tipped for pouring out the metal; lifted out with facility when it required to be changed; and that the man in charge of the ladle should be in a good position for turning it over, so that he could not only see well what he was doing, but be out of danger from any splashings of metal. 2nd. That all turn-tables and lifts should be avoided. 3rd. That in order to produce the utmost economy the ladle should be brought as near as possible to the blast furnaces, so as not to cool the metal

or have more scrap than necessary, and that the metal should be poured directly from the ladle into the converters, in order to avoid the cost and waste of runner-making."

"English experts have agreed very generally with Mr. Snelus in this matter. As to the avoidance of lifts, it is hardly fair to refer to the fact that he is about to use one, with his 20-ton mixing ladle, for his plant is so arranged that he cannot well avoid it."

In speaking of the saving resulting from the mixing of metals taken from the blast furnaces or the cupolas at the West Cumberland iron works, Mr. Holley says: "These savings amount to $1.25 gold per ton on rails."

Under the head of "unfinished works," in speaking of the works nearly completed at Moss Bay, a suburb of Worthington, Mr. Holley says: "Standing upon the general floor there is to be a 60-ton reverberatory, coal-fired furnace, or else there will be two 40-ton furnaces—this point had not been settled when I was
342 there, although the rest of the plant was nearly done, * * * or, by means of another lift or crane (not yet constructed), the ladle may — lifted to such a height that its contents may be tapped out into the large reverberatory furnace. In this furnace it is the intention to store and keep hot some 60 tons of iron from all the blast furnaces. The vessel charges will be tapped out as required into a ladle, raised by the high-jib crane, and poured into the vessel."

In speaking further of the use of this large reverberatory furnace, Mr. Holley says: "It is but fair to Mr. Z. S. Durfee to state that he has long advocated the use of a large Siemens furnace to melt and mix metals for the converter, principally for the purpose of using irons low in silicon, so as to save waste; he would substitute the heat imparted in the gas furnace at the expense of coal for that generated by the combustion of silicon at the expense of iron."

In speaking of a Bessemer plant nearly completed near Middlesborough for Messrs. Bolckow, Vaughn & Co., Mr. Holley says: "There are two plants having two vessels each, also six blast furnaces in a line. The tap-holes of the latter stand 10½ feet above the railway on the general level, so that the metal readily flows into the ladle. At the converting-house a few hundred feet away, the ladle carriage is lifted between the converters by a hydraulic hoist; thence it is run upon a traverse table on the platform in front of the converters, so that the ladle may be tipped directly into either of them. This arrangement is illustrated by engravings in 'Engineering,' November 10, 1876."

Speaking of the practice at Terrenoire, Mr. Holley says: "Two furnaces are tapped into the ladle to make a Bessemer charge. The ladle car is hoisted to the level of the vessel, run forward, and tipped into a short spout leading to the vessel."

Under the head of "conclusions," Mr. Holl-y says: "Fourth: But if the storage of a large quantity of iron in a reverberatory furnace or other reservoir, should prove successful, then a few
343 blast furnaces, making even an irregular product, and, if

necessary, working in connection with cupolas, would largely economize the Bessemer manufacture.

"In fact, this mixing of irregular irons on a very large scale, thus avoiding the expensive niceties of ore selection, and the necessity of many furnaces, is the theoretical key to the situation. When the way to its successful adoption is demonstrated, the direct process will undoubtedly have great advantages, even over the present practice on the continent, which employs manganiferous ores. But until this large scale mixing is developed, it should not appear that the use of our comparatively irregular blast-furnace metal, and more especially the use of part blast-furnace and part cupola metal, can result in any substantial saving." * * *

"So that, while we congratulate ourselves that the direct-metal users have no large advantages over us in the present state of the art, we may look forward to the development of the metal-storing problem with good hope, not only of more economical manufacture, but of more uniform product."

In reviewing these statements of Mr. Holley it is evident to me that in 1877, at the leading Bessemer works in Europe, there was a very perfect knowledge of the economies resulting from the mixing of metals taken from various blast furnaces in a receiver or vessel, placed between the cupolas or other smelting furnaces, and the converting vessel.

It is evident that the receiving vessels used held a number of charges of the converters in which the metal was converted into steel.

It is evident therefore, that when a single charge for conversion was removed from one of these vessels, there was more or less iron remaining.

And, in comparing the practice described by Mr. Holley with that of Jones, as set forth in the patent in suit, I have no hesitation in saying that the European practice in 1877, as described by
344 Mr. Holley, was substantially the same in intent, purpose and operation, as that disclosed by Jones in the patent in suit. In each case the intent was to produce an average quality of metal for the purpose of conversion, by mixing metals from several furnaces in a ladle or other receiving vessel.

And I can conceive of no reason why the means described by Mr. Holley, as used in Europe in 1877, should not be equally as efficient as those disclosed by Jones in the patent in suit.

I now refer to an English patent granted to John Loude Tabberner, No. 2161 of 1856, for certain improvements in smelting ores.

On page 4, line 4, the inventor says, "The object and intention of this invention is, therefore, to dispense with the necessity for employing one or more large furnaces, and to use in lieu thereof, several small furnaces, the combined capacities whereof are equal to that of one or more large furnaces, and to cause these small furnaces to discharge their contents at short intervals of time, into one large reservoir, from which the molten metal may be drawn for casting from. And it is the above principle of constructing and arranging furnaces, and the directing of blast to any particular part

thereof, at discretion, which I claim as constituting my invention of improvements in smelting ores."

In comparing this patent of Tabberner's with the patent in suit, it is clear to me that Tabberner understood fully the art of mixing metals from a number of smelting furnaces, in one large reservoir, from which the molten metal may be drawn for use as required. And Jones also understood this; and so far as the mixing of metals was concerned, when taken from different furnaces, I regard Tabberner's method as substantially the same as that of Jones.

There are other patents and publications in evidence, relative to the state of the art of making metals in a common receiver, these metals being taken from different furnaces, and mixed in the
345 receiver, from which the metal is withdrawn for conversion as required. But I do not think it necessary to take the time to review them.

Q. 12. Having reviewed these several patents and publications, please enumerate which of them, if any, in your opinion, discloses the method of mixing metals described in the Jones patent in suit.

A. In answering this question, I will refer to the British patent to Wm. Deighton No. 3672, dated November, 1873.

I also refer to British patent issued to Charles Denton Abel, as a communication from Zoheth S. Durfee, No. 685, March 6th, 1872.

I also refer to a letter by Z. S. Durfee, published in "Engineering," a periodical published in London in 1874, vol. XVIII, page 310.

I also refer to United States patent granted to James P. Witherow, No. 327,425, dated September 29th, 1885.

I also refer to United States patent granted to James P. Witherow, No. 316,587, dated April 14th, 1885.

I also refer to a certified copy of an article entitled "The use of molten iron direct from the blast furnace," contained in a publication entitled "The Journal of the Iron and Steel Institute;" 1876, London.

I also refer to a certified copy from the bound volumes of the library of the Patent Office, on pages 348 to 367 inclusive, and relative drawings, from the publication entitled "The Journal of the Iron and Steel Institute," London, 1874.

I also refer to an English patent granted to Henry Bessemer, No. 566, and dated 23d of February, 1869.

I also refer to a publication called The Journal of the Iron and Steel Institute, published in 1875 in London.

I also refer to a certified copy of an extract from an article entitled "The manufacture of Bessemer steel and steel rails at the works of Messrs. Brown, Bayley & Dixon, Ltd., Sheffield," by
346 Mr. C. B. Holland, contained in a publication entitled "Journal of the Iron and Steel Institute;" 1878, London.

I also refer to the certified copy of an article entitled "American iron and steel works," No. 1, by A. L. Holley and Lenox Smith, contained in a publication entitled "Engineering;" Colburn, vol. XXIII, London, 1877.

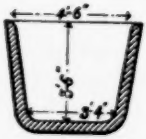
I now refer to a publication entitled "The Direct Use of Blast-

United States Circuit Court
Western District of Pennsylvania

Carnegie Steel Co. Limited
-vs-
Cambria Iron Co.

Defendants Exhibit
Deighton Capacity No. 1

J. W. Cormondo
Examiner



Vertical Section.

Deighton's Casting-ladle 1873.

Scale 1/4" = 1' Capacity = 8.47 gross tons.

Carnegie Steel Co.
v
Cambria Iron Co.
} p. 346a

United States Circuit Court - Western District of Pennsylvania.

Carnegie Steel Co. Limited

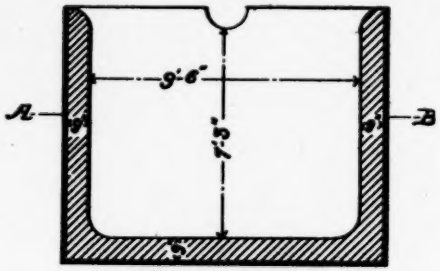
-vs-

Cambria Iron Co.

Defendants Exhibit

Deighton Capacity No. 2.

Fig. 1.



Vertical Section.

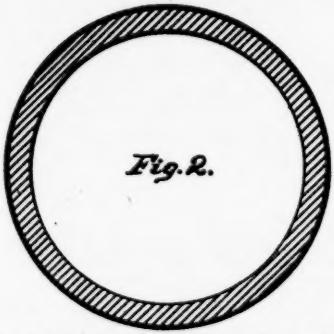


Fig. 2.

Horizontal Section on line A-B, Fig. 1.

Deighton's Receiving Vessel, 1873.

Scale ¼" = 1'.

Capacity - 103 gross tons.

Carnegie Steel Co. } p. 3446
Cambria Iron Co. }

furnace Metal in the Bessemer Process, No. 2, Second Series," published in New York by A. L. Holley in 1877.

I also refer to an English patent granted to John Loude Tabberner, No 2161, of 1866.

Q. 13. In commenting on the Deighton English patent, after stating the points of similarity between it and the Jones patent, you further state that you are of the opinion that with the apparatus of Deighton the same results can be obtained in practice as can be obtained by the apparatus of Jones. Now, that we may have a clear understanding of your testimony, will you please state whether or not, in your opinion, this Deighton patent discloses the method of mixing metal described in the Jones patent?

A. I have no hesitation in saying that I believe the Deighton patent does disclose the method of mixing metals described in the Jones patent in suit.

Defendant's counsel offers in evidence the sketches made by the witness and referred to in connection with his testimony as to the Deighton English patent, and the same are marked respectively "Defendant's Exhibit Deighton Capacity Sketches Nos. 1 and 2."

(Here follow diagrams marked pp. 346*a* & 346*b*.)

Q. 14. In commenting on the Witherow patent, No. 327,425, after stating the similarities between the apparatus of that patent and the Jones patent, you say that the practical steel-maker could from the Witherow apparatus, without difficulty realize all the economies and advantages that are of practical value in the Jones patent. Please state your opinion as whether the method of the Jones
347 patent would be practiced in the use of the apparatus described in the Witherow patent, and give your reasons therefor.

A. I am of the opinion that the method described in the Jones patent would be practiced by the use of the method described by Witherow. In the Witherow apparatus metal would be received from a number of smelting furnaces. It would be mixed in that apparatus by the mere act of pouring it in. Its mixture could be further facilitated by agitation. In the Witherow patent there are means provided by the use of which a definite quantity of metal can be withdrawn from the receiving vessel. In short, I am clearly of the opinion that the method disclosed by Witherow is substantially and for all practical purposes the same as the method disclosed by Jones in the patent in suit.

Adjourned by agreement of counsel, to Tuesday morning, 10.30 o'clock.

TUESDAY, *December 15th*—10.30 a. m.

Met pursuant to agreement.

Present as before.

Q. 15. State whether vessels adapted to retain large bodies of metal in a molten condition were known in the art prior to the Jones patent. If so, please specify examples?

A. Such vessels were known in the art prior to the patent of Jones. In the Deighton patent referred to, such a vessel is shown. In the Abel-Durfee English patent, an equivalent of a vessel, to wit, a reverberatory furnace, is clearly described. In the Witherow patents already referred to, such vessels are shown and described. I now refer to a United States patent, No. 238,110, granted to Wm. Hainsworth, February 22, 1881. In sheet 1, of the illustrations accompanying this patent, there is represented in figure 9, a vertical section of a ladle, with "a close top," (see line 25, page 3), s^1 having only a small opening, as at s^3; through which to fill it from the taphole of the spiegel cupola, and having a patent spout, s^2, on the opposite side."

348 I also refer to United States patent No. 55442 granted to Anton Lohage, June 5th, 1866. In this patent, on page 3, the inventor says: "I can successfully pour into my intermediate furnace, the contents of two to four, or even more, of the Bessemer converting vessels, according to the capacity of the furnace, and the construction of the steel works. The molten steel may remain half an hour, or longer, in the intermediate furnace, and in so long a time it is practicable to make a second conversion in the Bessemer converting vessel, and this extra quantity can be added to the first in the furnace."

For many years before the issuance of the patent in suit, it was a common practice in foundries, to accumulate metal in a receiving vessel, by tapping one or more furnaces into this vessel. The object of doing this was to get an average quality of the metal melted in the cupolas, for use in the foundry, and also to enable the smaller ladles used for carrying the metal to the molds, to be supplied with metal conveniently, without the necessity of tapping the furnaces when such supply is needed.

Q. 16. State whether vessels adapted to receive and retain molten metal, and adapted to be moved by tilting or oscillating, for receiving or pouring out the molten metal were known in the art prior to the Jones patent. If so, specify examples.

A. Such vessels were known in the art many years prior to the Jones patent. I used such a vessel myself, in 1864. The ordinary Bessemer converter is adapted to receive molten metal and pour it out by tilting. The ordinary large, foundry casting ladle, which is suspended by a bail and turns on trun-ions in the vertical arms of the bail, is adapted to receive molten metal and to pour it out by tilting. In the Hainsworth patent No. 238,110, already referred to, in Fig. 9, sheet 1, a vertical section of a tilting ladle is shown.

349 In the United States patent No. 33446, granted to John W. Nystrom, October 18, 1861, there is shown in Fig. 1 and Fig. 2, sections of a vessel adapted to receive metal and pour it out by tilting.

In the English patent No. 4920 of 1887, granted to Alfred Longsdon, there is shown, in sheet 1, sections of a vessel capable of rotation, adapted to receive metal and pour it out by such rotation.

Q. 17. State whether vessels adapted to contain bodies of metal in a molten condition and provided with covers to retain the heat

within the vessel, were known in the art prior to the Jones patent. If so, please specify examples?

A. Such vessels were known in the art long prior to the issuance of the Jones patent. The ordinary reverberatory furnace in which iron was melted, for the purpose of making castings and other uses, was substantially such a vessel. Furnaces in which iron was puddled were such vessels. The furnace described in the Abel-Durfee patent already referred to, was such a vessel. The United States patent of Witherow, No. 327,425, September 29, 1885, already referred to, shows such a vessel.

The United States patent to Wm. Hainsworth, already referred to, shows in Fig. 9, page 1, a section of such a vessel.

United States patent to John W. Nystrom, already quoted, shows such a vessel.

In the English patent to Alfred Longsdon, already mentioned, there is shown a vessel of this kind.

The patent to Anton Lohage, already quoted, shows a vessel of this sort.

Q. 18. State whether vessels adapted to hold molten metal or metal under treatment had been mounted to turn while supported on friction rollers, prior to the Jones patent. If so, please specify examples?

A. Such vessels had been known long prior to the Jones patent. The ordinary revolving puddling furnace, known as the
350 Danks furnace, also a modification of the same known as the Sellers puddling furnace, was supported on friction rollers. In the United States patent to Nystrom, already quoted, and in the English patent to Alfred Longsdon, already quoted, vessels supported on friction rollers are shown.

In the United States patent No. 212,168, granted to R. A. Atwater, February 11th, 1879, and in the United States patent No. 120,005, granted to John Y. Smith, October 17th, 1871, vessels supported on friction rollers are shown.

Q. 19. It is in evidence that at the works of A. Whitney & Sons in Philadelphia, Pa., prior to the Jones invention, it was the custom to tap the molten pig metal at intervals during the day, from three cupola furnaces, into a large ladle holding from 12 to 15 tons of metal, and from time to time to withdraw from this large ladle small charges, into ladles holding about 600 pounds of molten metal, for casting car wheels, this practice being followed intentionally, to obtain a more uniform metal; and that, practically, the same practice was followed at Altoona, Pa., in the car-wheel foundry of the Pennsylvania railroad. Please state whether, in your opinion, such practice embodies the method of mixing metals, described in the Jones patent in suit.

Question is objected to, because in the opinion of complainant's counsel, it does not wholly or accurately summarize the testimony referred to.

A. In answering this question, I will say that I saw the apparatus referred to as having been used in the Whitney works, in use at

that works in 1864, and I also saw the apparatus said to have been used at Altoona in use many years before the issuance of the patent in suit. In both of the Whitney and Altoona works the metal was received from the furnaces, and mixed in a receiving vessel, in precisely the way described by Jones in his patent in suit. In that patent, line 83, page 1, Jones says: "To this end my invention may be practiced in a variety of forms, of apparatus—for example,
351 by merely receiving in a charging ladle a number of small portions of metal taken from several ladles or receiving vessels, containing crude metal obtained at different times or from different furnaces, the mixing being performed merely by the act of pouring into the charging ladle, and other like means may be employed."

The means employed at the works referred to, would be accurately described by the latter part of the above quotation, to wit: "The mixing being perfocmed merely by the act of pouring into the charging ladle."

Q. 20. In answering the last question, have you considered the facts stated in it, that small charges were withdrawn from time to time from the receiving ladle, into which the metal was tapped from the cupolas from time to time? If so, has this any bearing on the practice in the Jones method?

A. From the receivers in the works referred to, small quantities of metal were withdrawn from time to time for use in the foundries, as required, without entirely draining or emptying the receiving vessel. In the patent in suit, in claim 2, line 51, page 3, Jones claims "removing portions only of the composite molten contents of the receptacle, without entirely draining or emptying the same, and successfully replenishing the receptacle with fresh ununiform additions, substantially as and for the purposes described."

In the foundries of Whitney and Altoona the receiving vessel was replenished from time to time with fresh ununiform additions of metal, precisely in the way described by Jones.

Q. 21. It is in evidence that at the Bessemer department of the Pennsylvania Steel Co., at Steelton, Pa., prior to the Jones invention, it was the custom to tap the molten pig metal at intervals during the day from five cupolas, by a common runner, into a large receiving ladle, which at times held over 35,000 pounds of molten metal, from which converter charges of from 14,000 to 17,000 pounds were withdrawn at intervals, as needed, leaving remaining
352 in the ladle, after withdrawing such charge, from 5,000 to 20,000 pounds; and that a like general practice prevailed at the works of the Cambria Iron Co., and the Lackawanna Iron and Steel Co. Please state whether in your opinion this practice embodied the method of mixing metals described in the complainant's patent in suit.

Complainant's counsel objects to the summary of the testimony given by defendant's counsel, for the reasons stated in the preceding objection, and also because the rules of evidence do not permit counsel thus to assume to state from the record what he conceives

to be the effect of the testimony, and to represent it as the testimony actually given.

A. The process described as having been used in the works referred to in this question, I regard as embodying and disclosing the same method of operations as is claimed by Jones in the patent in suit. The metal is taken from a number of furnaces; it is mixed in a common receiving vessel, and is withdrawn from that receiving vessel from time to time as required, without draining the vessel, and this vessel is replenished from time to time, as necessary. I regard the operation as practically the same as that described and claimed by Jones in the patent in suit.

Q. 22. It is in evidence that prior to the Jones invention it was the custom at the Fort Pitt foundry of Knapp, Wade & Co., Pittsburgh, and at the Fulton foundry of Totten & Co., Pittsburgh, to run the metal from the cupola into a large ladle, either continuously as it melted, or at intervals, and to pour small portions from this large ladle into smaller ladles for casting, without entirely draining the large ladle. Please state whether, in your opinion, this practice embodied the method of mixing metals described in the Jones patent.

Objection repeated.

353 A. I fully believe that the process described involved the process of mixing metals described in the Jones patent. As the metal taken from the cupola from time to time would not be uniform, and these ununiform portions of metal would be mixed in the receiving ladle, and an average quality of metal would result from such mixing, and this metal would be taken from time to time for use in the foundry as required. The practice described in the question is within my personal knowledge a very old one. I have employed it myself, and have known of its being employed long prior to the issuance of the patent in suit.

Q. 23. It is in evidence that prior to the Jones invention at the Fort Pitt foundry, Pittsburgh, guns were cast by simultaneously tapping the metal from three air furnaces by runners, into a pool holding three or more tons of metal, from which the metal was carried by runner to the gun mold or molds. Please state whether, in your opinion, this practice embodied the method described in the Jones patent.

A. In so far as the metal from three furnaces was mixed in a receiver, it did involve the patent of Jones.

Q. 24. It is in evidence that prior to the Jones invention it was the custom at the Fulton foundry, of Totten & Co., Pittsburgh, in making large castings, to melt part of the metal in an air furnace, and the remainder in a cupola furnace, and to tap the metal from these two furnaces into a large ladle, permitting the metal to commingle, and then to pour it into the mold. Please state the bearing of such practice upon the method described in the Jones patent in suit.

A. Inasmuch as the metal obtained from the two furnaces referred to in the question, could not have been of uniform quality, and

these two uniform metals were mixed in a receiving vessel, and that an average uniform metal resulted, the method practiced was identical with the mixing described in the patent in suit.

354 Cross-examination by Mr. BAKEWELL:

X Q. 25. Is it better and more economical practice for the defendant to charge its converters with molten metal taken from the blast furnaces instead of employing metal which has been remelted in the cupola?

A. I think it is.

X Q. 26. Why?

A. Because by so doing the expense of remelting in the cupola is saved, and I think a better mixture of metal for use in the converter can be obtained by mixing the metals from several blast furnaces in a receiving vessel, than can be obtained by melting pig metal in the cupola. The metal taken from the blast furnace and converted direct would, I believe, blow hotter, as it is called, or work better, in the converters, than metal taken from cupolas, as the result of remelting.

X Q. 27. To how much does the saving in cost amount?

A. That is a question that is very difficult to answer in a general way. It would depend upon so many circumstances, each of which is liable to vary. Mr. Holley states in a paper already in evidence and quoted by me, that in the case of metal converted at the West Cumberland works, in England, the saving amounted to $1.25 per ton for steel produced. He also states that under certain conditions which he suggests, the saving might be more than that.

X Q. 28. About how much do you think the saving amounts to in the case of the defendant's operation?

A. I have no means of knowing. I never heard the saving named, and I do not know the price of his materials, or of any one of them.

X Q. 29. Do you think it is a substantial saving?

A. I should suppose it was, or the process would not be used.

355 X Q. 30. Are you of the opinion that by use of its mixing apparatus which has been described in the proofs the defendant is enabled to effect this economy of operation which you have mentioned, without, at the same time, deteriorating, but rather improving, the character of the steel which it obtains from its converters?

A. I think the steel produced would be likely to be better than if the metal was remelted in cupolas.

X Q. 31. Will you please describe the operation of making Bessemer steel from remelted pig metal, beginning your description from the time when the metal is tapped from the blast furnace and ending at the time when it is remelted in the cupolas.

A. The ore is first smelted in the blast furnace, and when the crucible or lower part of the furnace is sufficiently full of metal a tap-hole is opened, and this metal is then run out into molds made in the sand floor of the casting-house connected with

the blast furnace. In some instances molds made of iron are used, instead of molds made in the sand of the floor. This last method, however, is not generally employed. These molds in the floor of the casting-house are usually semicylindrical at the bottom and rounded at their ends. They are open at the top, and the metal cast in them takes the form of the molds and is technically called a pig. In the best practice, when these pigs are cold enough to handle, the whole of the pigs made from a single tapping of the furnace are laid side by side in a row in the stock yard of the furnace. The next tapping of the furnace will be placed on top of these in a similar row, one thickness of pigs in height. This process of building up a pile of pig iron of each successive tapping of the blast furnace is continued until the pile of pigs becomes as high as convenience dictates. Then another pile of pigs is built up in the same way. The metal for melting in the cupolas is then taken from each pile at their ends, care being taken to cut the pile vertically and transversely and thus selecting pig from each cast or
356 tapping of the blast furnace of which the pile is composed. In this way an average quality of iron can be obtained, representing the average quality of iron produced by the blast furnace. And in a case where several furnaces are employed in smelting a better average can be obtained by mixing pigs resulting from the tapping of each furnace in layers in a similar way. The pig iron from such piles as I have described is taken from their ends, as I have stated, and carried to the cupolas, and is there mixed with the fuel used by charging alternate layers of iron and fuel into the top of the cupola. The fuel employed is either coke or anthracite coal, or a mixture of the two. Blast is applied to the cupola, and a charge of iron is melted.

X Q. 32. In tapping metal from a cupola furnace, how is the flow of the metal started from the furnace?

A. In tapping metal from the cupola furnace the stopper of the cupola near the bottom of the interior is opened by a bar of iron. The metal is allowed, when the bar is withdrawn, to run through the aperture so made.

X Q. 33. Can the flow of the metal from the cupola be conveniently stopped until the furnace has been emptied of metal?

A. It can.

X Q. 34. How?

A. By putting masses of soft clay, which is kept for the purpose, upon the end of a bar of iron, and driving this clay by means of a bar into the aperature through which the iron is flowing from the cupola.

X Q. 35. And can that be conveniently done while the iron is still flowing in a substantial stream?

A. It can. I have seen it done in cupola practice a great many hundred times.

X Q. 36. Is it more convenient in cupola practice, when the furnace is tapped, to let the iron continue to flow until the furnace is empty, rather than to tap off only small portions at a time?

357 A. Of course, the larger amount of metal that is taken from the cupola at a single tapping the less number of tappings in the course of a day will be required than if small amounts were tapped at comparatively short intervals. The fewer the tappings the less labor involved in the operation.

X Q. 37. What would be the objection to charging a converter with unmixed metal, taken directly by a ladle from the blast furnace to the converter?

Objected to as assuming a fact to which the witness has not testified.

A. In some instances this has been done. Not merely experimental, but as a regular practice. But blast furnaces do not always run with perfect regularity. The metal of the different tappings is liable to vary, and if there is much variation in the tappings, if successive tappings were used for conversion into steel, the steel also would be likely to vary in quality. For the conversion of molten pig iron into steel it is desirable that the metal be as uniform as to quality as possible.

X Q. 38. If the metal charged into the converter should contain, for example, an excess of silicon, what would be the effect?

A. If the silicon was very largely in excess the heat in the converter might be excessive, and the steel, when poured from the converter, might be of an inconveniently high temperature.

X Q. 39. And what is the result if the silicon content of the iron charged into the converter is too low?

A. The charge would be liable to blow in the converter cold and the metal when poured from the converter into the casting ladle, might be of so low a temperature as to make it difficult to get it into the ingot molds and the metal might even chill in the casting ladle, forming what is called a "scull."

X Q. 40. So far as you know, personally, did any manu-
358 facturers of steel in the United States, prior to the complainant's use of the Jones mixer, employ with uniformity of product, the direct process of making Bessemer steel?

A. At Wyandotte, in Michigan, in works designed and erected by myself, and run under my supervision, the first steel made in America by the Bessemer process, was made from metal taken directly from the blast furnace into a receiving ladle, and from thence to the converter. The steel that was made in that way was fairly uniform in character. At South Chicago metal was taken directly from the blast furnace to the converters several years prior to the Jones patent. I was assured by the managers of those works, at that time, that the product was entirely satisfactory. The steel produced was run into rails. I was told that nearly the whole of it was used for that purpose.

X Q. 41. And this South Chicago works, afterwards adopted and used a mixing vessel substantially like that of one or both of the parties to this suit. And did so after the date of Jones' patent, is that not so?

Objected to as improper cross-examination.

A. Not to my knowledge. I have never seen any such vessel there and I have never been told that any such was used.

X Q. 42. When were you there last?

A. I think it was in 1885.

X Q. 43. How long did the Wyandotte works continue to practice the direct process?

A. Under my supervision the works were run from about September, 1864, to June, 1865. We did have, in those works, a reverbatory furnace for remelting what we called foreign iron, that is, iron that was not produced in that locality for experimental purposes.

X Q. 44. Will you please state what a reverbatory gas furnace is?

A. A reverberatory gas furnace is a chamber of firebrick. Its walls are usually vertical, and its roof usually arched. These
359 furnaces vary in size and general dimensions, according to the use to which they are put. The bottom of the furnace, or floor, forms a basin, in which the metal melted in the furnace is contained. The furnace is fired or heated by burning gas. This gas enters at one end of the furnace, passes over the metal to be melted, and any waste heat passes out at the other end of the furnace. In the type of a reverberatory gas furnace known as the Siemens furnace, there are a number of valves by which the supply of gas and air for its combustion can be regulated; and by which the gas and air can be made to enter at either end of the furnace, and the waste heat pass off at the opposite end, at pleasure.

X Q. 45. If a charge of molten pig iron be introduced into the hearth of such reverberatory gas furnace, and the flame be caused to pass over the same, as you have described, what effect does it have upon the composition of the metal?

A. The effect will depend upon the character of the flame and the amount of gas burned in a given time.

X Q. 46. Your answer accounts for the degree of the action, but apparently not for the kind. If I am correct in this suggestion, will you please answer further?

A. There are several kinds of effect that might be produced, depending upon the character of flame and the amount of gas consumed in a given time, as I have said before. If there is an excess of air supplied with the gas, that is, a greater amount than is necessary, to merely consume the gas, the highly heated oxygen in this excess might act upon the metal in the hearth of the furnace; that is, if the surface of this metal was not properly protected by a coating of liquid cinder from such action. Then, again, if there was not sufficient air supplied to consume all the gas, the temperature of the furnace might not be sufficiently high; and, further, if there was a large amount of gas supplied, and air enough just to merely consume that gas, the temperature of the furnace
360 might be unduly high. These circumstances of air and gas can be regulated by the operator of the furnace at pleasure.

X Q. 47. In the first of the cases which you have named, viz., the presence of too much air, the flame would tend to desiliconize the metal in the furnace, would it not?

A. If the operator of the furnace was careless enough to allow such a condition to exist, the tendency would probably be to desiliconize the metal in the furnace to a greater or less degree; that is, if the metal were not properly protected by a coating of liquid cinder from the action of the excess of air. A furnace of that kind is so easily regulated, as regards the character and volume of the flame in it, that there would be no difficulty whatever for a skilful operator to prevent any injurious action upon the metal of the gas and air supplied to the furnace.

X Q. 48. Generally speaking, what is the difference in the composition of pig metal suitable for use in the Bessemer converter, and the composition of pig metal suitable for foundry work—*i. e.*, for the manufacture of castings?

A. That is a very difficult question to answer briefly. Some metals used in foundries for making castings would make excellent metal for steel; some metal used in the foundries would make nothing but poor steel, treat it as you will. For some castings, one kind of metal would be especially suitable; for other castings that sort of metal would not answer at all.

X Q. 50. What are the characteristics of good pig metal for the manufacture of Bessemer steel?

A. It is considered desirable that pig metal for the manufacture of Bessemer steel should have 4 or 5 per cent. carbon present in it; 2 to 3 per cent. of silicon, and very little phosphorus and sulphur; the less the better.

Adjourned, by agreement of counsel, to Wednesday, December 16th, 1896, at 10.30 a. m.

361 WEDNESDAY, *December 16th*, 1896—10.30 a. m.

Met according to agreement.

X Q. 51. What is a cupola?

A. It is a structure made of firebrick or other refractory material, usually enclosed in a casing of iron and usually cylindrical in form, on its inside and out. This structure stands upright beneath a chimney. There is an opening at a convenient height for supplying it with fuel and the metal to be melted; and at a suitable height above its bottom, it is provided with one or more tuyeres, through which a blast of air is supplied to its interior. Near the bottom of the furnace there is a tap-hole, through which the melted iron can be withdrawn from time to time, as required. This tap-hole can be closed with a stopper of clay or similar material. There is also an aperture in the side of the cupola, through which the cinder which accumulates on the surface of the molten iron in the lower part of the cupola can be withdrawn.

X Q. 52. This tap-hole of which you speak is a simple round hole, extending through the furnace wall, below the level at which the melted iron stands before tapping; this hole is closed by a plug of clay and the furnace is tapped by knocking out this plug from the outside by means of a bar, is that not correct?

A. The furnace is tapped by driving a bar through this plug of

clay into the interior of the furnace, and if the iron does not happen to flow fast enough through the hole so made the aperture can be enlarged by a bar from the outside. I believe the question otherwise than modified by my answer, is in the main correct.

X Q. 53. Would your last answer apply also with correctness as a description of the tap-hole of a reverberatory gas furnace containing molten metal in its hearth?

A. It would.

X Q. 54. Would it also apply with correctness as a description of the tap-hole of the patents of Witherow?

362 A. In the Witherow patent No. 327,425 there is represented a series of tap-holes at different heights in the side of the receiving vessel *b*, sheet 2. In the Witherow patent No. 315,587 there is one tap-hole *j*, shown in the receiving vessel E, and also a tap-hole *u*, shown in the blast furnace D. There is also a tap-hole *h*, shown in the stationary converting vessel C. These tap-holes I judge to be the same from the drawing, as the tap-holes in the cupola furnaces and reverberatory furnaces which I have described.

X Q. 55. And would the same answer also apply with correctness as a description of the tap-hole of Deighton's British patent No. 3672 of 1873?

A. I believe the tap-hole in the receiving vessel *a* shown in figures 4 and 5, of the drawings accompanying the Deighton patent, to be substantially the same in construction as those I have described as used in cupolas and reverberatory furnaces.

X Q. 56. Would the same answer apply also with correctness as a description of a tap-hole in the apparatus of Durfee's British patent of 1872, which you have discussed in your direct deposition?

A. Durfee speaks of the metal being "tapped out from time to time as may be required." From that statement I am disposed to believe that Durfee's reverberatory furnace had a tap-hole, and the tap-holes of reverberatory furnaces used in the arts at the time of the issuance of Durfee's patent were constructed and operated substantially the same as those I have described as used in connection with cupola and reverberatory furnaces.

X Q. 57. Will you please state where you got the dimensions for sketches of Deighton's apparatus which you have submitted in your direct examination?

A. I have carefully examined the drawings accompanying the Deighton patent, and from my knowledge of the size of converters in general use at the time, and from the gauge of the

363 railway tracks represented in figure 5, beneath the suspended casting ladle *l*, figure 5, I arrived at the conclusion that the drawings were made to a scale of ½ of an inch to a foot; that is to say, ½ of an inch on the drawing representing a foot of the actual apparatus. From that data and a measurement of the drawings I arrived at the conclusion as to the capacity of the vessel shown in the sketches.

X Q. 58. Is it not a fact that in your sketches you have shown the vessel as being about two and a quarter times the diameter of the casting ladle at the top, whereas in the drawing of the patent

the vessel *m* is considerably less than twice the diameter of the ladle at the top? See figure 5 of the patent which shows both the vessel *m* and the casting ladle.

A. In applying the scale of an $\frac{1}{8}$ of an inch to the foot, the upper edge of the casting ladle *l*, Fig. 5, I find its external diameter to be 6 feet and 6 inches. On measuring the external diameter of the receiving vessel *m*, in the same drawing, by the same scale, I find it to be 11 feet and 6 inches.

X Q. 59. Will you please, in the same way, let me know the vertical dimensions of the casting ladle *l* and the vessel *m*, in figure 5 of the patent, wherein both are represented?

A. In measuring the exterior vertical height of the ladle *l*, shown in the drawing, by the same scale, I find it to be five feet; in measuring the external vertical height of the receiving vessel *m* by the same scale I find it to be nine feet.

X Q. 60. Now will you please state what are the corresponding horizontal and vertical dimensions of the casting ladle *l* and vessel *m*, as shown in the two sketches which you have produced and which were offered in evidence.

A. The horizontal external diameter from the top of the casting ladle is five feet; the vertical dimension is four feet. I find
364 in the drawing that I have submitted that I have inadvertently made an error of one foot in the vertical dimensions of the casting ladle. This sketch was made late in the evening, and this error was entirely unintentional. And in the horizontal dimensions I find there is also an error in my drawing of 6 inches. The casting ladle in the patent being 6 feet 6 inches, and in my sketch it is five feet.

X Q. 61. Referring to the patent of Witherow, No. 327,425, what would be the effect upon the silicon content of the metal, in the receptacle *b*, if air should be blown down upon the metal, through the tuyeres *g*?

A. Unless the metal was properly protected by a coating of liquid cinder, some of the silicon might be oxidized.

X Q. 62. And if the surface of the metal were protected by a layer of cinder, would the blowing of air through the tuyeres upon the metal be of any utility for Witherow's purpose?

A. If the air is used to promote the combustion of gas, such combustion would result in maintaining the heat and fluidity of the metal in Witherow's receiver.

X Q. 63. But if the air is blown through the tuyeres without gas, how would you answer the last question?

A. There might arise from the metal in the bath through the liquid cinder, some combustible gases, in which case the air supplied would ignite these gases and so produce heat to keep the metal fluid. In the puddling operation in the manufacture of wrought iron, such combustible gases always separate from the liquid iron under treatment and burn on its surface.

X Q. 64. In the patent of Witherow, No. 327,425, and in his patent No. 315,587, is it not a fact that the molten metal, when it is tapped from the blast furnace or furnaces runs directly from the

furnace tap-hole through a spout into the receptacle, and is not collected in ladles at the furnace tap and carried in the ladle to the receptacle?

A. That is the fact, as I understand the drawing accompanying the Witherow patents.

365 X Q. 65. And the same is true, also, of the apparatus of the Deighton English patent, is it not?

A. That is the fact, as I understand the drawings accompanying this patent.

X Q. 66. And in the foundry practice to which you have referred, in the direct examination, do you understand it to have been the practice to tap the metal from several cupolas directly into the common vessel, from which it was drawn into the casting ladles, and not to tap the cupola furnaces severally into ladles whose contents were afterwards poured into a common ladle?

A. That was the practice as I understand it.

X Q. 67. In the patent of Jones in suit the specification describes the collecting of the metal at the blast furnaces in ladles, which are carried severally to the common mixing vessel, and are poured into the same, as required, is that not so?

Objected to if complainant is conveying the idea that this is the only procedure described in the Jones patent.

A. Jones states that he uses a charge (line 61, page 1 of his patent), "composed not merely of metal taken at one time from the smelting furnace, but of a number of parts taken from different smelting furnaces, or from the same furnace at different casts; or at different periods of the cast and subject the metal before its final refining to a process of mixing, whereby its particles are diffused or mingled thoroughly among each other." That I understand to be substantially the idea of Jones. I do not understand that he confines himself to a specific form of apparatus; for he says, in describing his invention (line 82, page 1), that his invention may be practiced in a variety of forms of apparatus. In the forms shown in the drawing, accompanying the patent, he illustrates a ladle for bringing the metal from the blast furnaces to his receiving vessel, and from this ladle the metal is poured into that vessel.

366 X Q. 68. And is it not a fact also that in every form of the apparatus, which Jones particularly describes, namely, the mixing of the metal in a charging ladle, and the mixing of the metal in a vessel, marked 2 in his drawing, the metal is not described as being tapped directly from the blast furnace, into the vessel in which it is mixed, but is described as being tapped from the blast furnace into ladles, or "receiving vessels," the contents of which are afterwards poured into the mixing vessel, whether it be the charging ladle, or the special vessel 2. If possible, will you please answer this question by a simple affirmative or negative and you may then proceed to explain or qualify your answer as you please?

Objected to as immaterial, in view of the testimony of complainant's witness Gayley.

A. The apparatus described by Jones does represent a ladle for taking the metal from the blast furnaces and pouring it into his receiving vessel; but as I understand his invention, that is simply a matter of convenience; for some particular location or arrangement of blast furnace and receiving vessel. I am justified in this belief by the statement of Jones on page 2, line 44, of his patent. Where he says: "For convenient use of the apparatus, I found it best to so arrange it, that it is adapted to receive its charges of metal from cars or bogies 7." I do not find that Jones insists upon this particular form of apparatus as being essential to the carrying out of his invention.

X Q. 69. But do you find anywhere in Jones's patent a statement that the metal may be run directly in spouts from the blast furnace to the mixing vessel? If so, please quote instances?

A. Jones does not specifically state that the metal may be so taken; but he does imply that it is a matter of choice by an intelligent metal-urgist as to just what method he may adopt, to
367 carry out the invention. Jones specifically states (page 1, line 81), that "my invention may be practiced with a variety of forms of apparatus." And the form which he chooses to describe, I understand to be only one of many forms of apparatus that may be used.

X Q. 70. And is it not a fact that immediately following the part of Jones' patent you have just quoted, and in the same sentence, he states: "For example, by merely receiving in a charging ladle a number of small portions of metal, taken from several ladles or receiving vessels containing crude metal obtained at different times or from different furnaces, the mixing being performed merely by the act of pouring into the charging ladle, and other like means may be employed." And immediately thereafter follows a statement that he prefers to employ, not the charging ladle, but the mixing vessel 2, which he afterwards proceeds to describe particularly. I suggest that if you will kindly answer the question directly, it will conduce to a shortening of the examination.

A. It is evident that Jones made the statement referred to in the question; but I regard that statement as merely an example of one method of carrying out Jones' invention. And the method illustrated in the drawings, as the one which he himself prefers. But he evidently contemplated a variety of forms of apparatus, as he specifically so states.

X Q. 71. How many forms of apparatus does he specifically describe for mixing the metal?

A. I have stated what I understand his drawings to represent; but he evidently clearly recognized the possibility of the carrying out of his invention "with a variety of forms of apparatus."

X Q. 72. Question repeated.

A. In answering the question, I referred to a previous answer of mine in reply to X Q. 70, in which I said, "the method illustrated in the drawings as the one which he himself preferred."

368 X Q. 72½. As you have not yet answered my question I must repeat it and ask you to state how many forms of apparatus does Jones specifically describe in the text of his specification for mixing the metal, one, two, three, or what?

A. Jones describes the one form of apparatus which he prefers.

X Q. 73. But do you not find a description of one form of apparatus, namely the charging ladle, in which a number of small portions are poured from several ladles, as on line 84 of page 1, and second, a description of the vessel 2, beginning line 5 of page 2, making in all two forms of apparatus, specifically described for mixing the metal?

A. The quotation first referred to in the question is merely a suggestion, and I hardly think it could be considered as a specific and detailed description of the apparatus preferred. Apparatus might be designed to carry out this suggestion in various different ways. The other description to which reference is made in the question, is in detail and refers specifically to the drawings, and as I understand it, describes the form of apparatus which Jones himself prefers.

X Q. 74. Is any drawing necessary to illustrate what a charging ladle is?

A. There are different forms of charging ladles, and they are manipulated in different ways. Therefore, in order to explain clearly just the form of charging ladle employed in a particular case, a drawing would be necessary.

X Q. 75. Do charging ladles differ from each other otherwise than in mere shape and size? I mean charging ladles, such as used in Bessemer practice.

A. I have seen two forms of charging ladle used in Bessemer practice, one of which is provided with trunnions, and supported by a carriage running from wheels. The other of which is provided with trunnions which are connected with a bail, by means of which the casting ladle is hoisted and moved by a crane.

369 X Q. 76. And do you wish to be understood as saying that the operation described by Jones on line 84, page 1, would be substantially different if one of these two forms of charging ladle were employed, from what it would be if the other were used?

A. What I do mean to say is this: That in order to understand the particular form of charging ladle used, in a case where metal was mixed in a charging ladle, clear and specific drawings would be required; as clear and specific relative to the charging ladle, as the drawings in Jones' patent, which illustrate the form of apparatus which he prefers. I regard, as I have before stated, the example of the use of the charging ladle as being a mere suggestion and not a specific description of apparatus, such as is given of the apparatus which Jones prefers.

X Q. 77. Question repeated.

A. The mixing of the metal in the two forms of charging ladle would be substantially the same.

X Q. 78. And don't you think that the necessity for drawings is quite as important to be found in prior publications and patents

which are alleged to anticipate the patent in suit, as they are in the patent in the suit itself?

A. I cannot answer that question generally; I can only speak of any particular case.

X Q. 79. In the patent of Hainsworth No. 238,110, the ladle to which you referred *to* upon the direct examination is a ladle for carrying spiegel eisen, is it not?

A. Yes, that was the spiegel ladle.

X Q. 80. In the patent of Nystrom, the tilting vessel to which you refer in your answer to Q. 15, was a converter, was it not?

A. The inventor speaks of the tilting vessel as the furnace F. I do not see that he speaks of it anywhere as a converter. In his second paragraph, page 1, he says, "My invention consists, first, in the construction of a barrel furnace."

370 X Q. 81. Is not Nystrom's apparatus, in fact, a species of converter, whether so described or not?

A. This barrel furnace of Nystrom may fairly be regarded as a species of converter.

X Q. 82. Is the same true of the tilting vessel described in Longsdon's British patent, of 1877?

A. The inventor Longsdon says, page 3, line 9, "The object of this invention is to apply one and the same furnace as a reverberatory and Bessemer furnace, so that when in one position it may be used as a reverberatory furnace, and when in another position, as a Bessemer furnace; whereby the charge may be treated as in a reverbatory furnace or have air blown through it, as in a Bessemer furnace, the operations may be carried on alternatively, as desired." I should say when the Longsdon furnace is turned upright as shown in figure 3, sheet 1, of the drawings illustrating Longsdon's invention, and air was blown through the tuyeres *h*, at the bottom, into the molten cast iron within it, the furnace of Longsdon was acting as a species of Bessemer converter.

X Q. 83. In the patent of Lehage, No. 55442, is it not a fact that the intermediate furnace of which you have spoken is a furnace into which metal is poured after it has been blown in a converter, and in which it is further heated, or as Lohage says, "superheated," and otherwise treated in order to bring it into condition for casting into ingots?

A. This furnace D of Lehage, sheet 2, Fig. 3, as I understand his invention, is intended to receive a number of conversions of steel and mix the same in order to accumulate metal of sufficient quantity for use in any way for which a single conversion of metal would be insufficient. And while the process of mixing and accumulation is going on, to maintain, and if necessary augment, the temperature of the metal.

X Q. 84. Question repeated.

371 A. The furnace of Lehage does receive metal after it is blown in the converter, and may receive in succession a number of conversions of such metal, and combine or mix the same; and this combined or mixed metal may have its tempera-

ture augmented if desired, while in the furnace D, and this mixed metal may be tapped out for the making of ingots or casting.

X Q. 85. Does not Lehage state in his specification, "In all cases the process must be continued till the molten steel and the steel or iron is added in the intermediate furnace, is overmelted or superheated, and the mass has become uniform"?

A. Lehage makes that statement.

X Q. 86. Please quote from the patent any language, if you find it there, which describes means for rendering the metal uniform other than the superheating of the metal, or adding to it alloys?

A. I do not see any other means described in the patent than those mentioned; but from my practical experience, I know that the result of combining a number of successive conversions of steel in such a furnace, as Lehage describes, would be to mix those successive conversions, and the result would practically be a uniform metal. I have, myself, made a great many hundred tons of casting of steel from metal poured into a receiving vessel from a great number of crucibles, and taken from that vessel into the molds. The result was always a product of uniform quality.

X Q. 87. Is not the paragraph of 11 lines, beginning at the last line, column 1, of page 3, the only description in the Lehage patent of the admixture of the product of several converters?

A. I do not think it is. On page 2, the inventor says at the commencement of that paragraph, "Figure 1, sheet 1, is a sectional elevation of a pair of Bessemer converters, B, B, conveniently arranged for the purposes of my invention. It will be seen
372 that between the two vessels is placed a crane, A, provided with a receiving vessel, C, into which the Bessemer metal is poured, for the purpose of conveying it to the intermediate furnace." It is evident to me that it was the intent of Lehage to take the metal from either of these vessels, or from both of them as desired.

X Q. 88. Have you now quoted all the language which in your opinion describes the mixing of the product of several converters?

A. Lehage says on page 3, "In order to operate upon steel, melted in the ordinary crucibles, or other melting furnaces, I simply pour the contents of each crucible through funnel *d*, into the intermediate furnace, or I gather the contents of several crucibles in a receiver previously heated, and then empty that receiver into the intermediate furnace." In the matter just quoted, the inventor Lehage does not speak of what is known as a Bessemer converter, but he does speak of the crucibles, and of several crucibles, because he says he pours the contents of each crucible through the funnel into the intermediate furnace. Those crucibles may be fairly regarded as small converters; for in them molten iron is converted into steel, and the steel in each crucible would, in all probability, be to some extent different from the steel in any other crucible. Therefore the intermediate furnace mentioned by Lehage is simply a receiving vessel for gathering the contents of several crucibles and producing a quality of metal which would be an average of that in the several crucibles by mixing their contents.

X Q. 89. Do you not think that fairness would require the word "simply" to be omitted from your last answer, in view of the fact that the metal is superheated in the furnace, and that this overmelting or superheating is specifically stated in the claim?

A. In case the temperature of this mixed metal was sufficiently high for the use for which the metal was intended, no further superheating would be required. The metal could be used
373 at once, after it was simply mixed and its quality thereby rendered uniform. But if for any cause the temperature should be too low, the inventor has provided means for augmenting it. From my experience I am sure that it would be possible, with crucible metal, to use this furnace of Lehage by simply mixing the metal within it for a long time, without giving it any additional heat, and therefore I am disposed to believe that the term "simply" mixing conveys a fair idea of the matter.

X Q. 90. Have you, in stating your understanding of the other patents to which you have referred, applied to them the same rule which you have apparently applied to the description of Lehage's apparatus, namely, describing the same with reference to what could be done, or might possibly be done, with the apparatus, although as in this matter of Lehage, the specification does not describe the actual doing of the same? I refer now to your statement that it is fair to say that Lehage's apparatus is simply a mixing vessel, because it might be used as a mixing vessel, simply.

A. In the answer just given, I did not intend to convey the idea that Lehage's furnace or receiving vessel would under all circumstances be simply a mixing vessel; but that it would be simply a mixing vessel when the temperature of the metal received in it and mixed therein was sufficiently high for use, without any further addition of heat, or any further treatment, than the simple mixing. My practical experience as a steel-maker teaches me that in very many instances and probably for a long period of working, when metal was taken into the furnace of Lehage from a large number of crucibles and mixed therein, that such mixture of metal would require no further treatment before it was used for the making of ingots and castings. For I have myself made a great many hundred tons of castings of steel from metal taken from a large number of crucibles, and mixed in a common receiving vessel, and run thence directly into ingots or molds, without any treatment whatever, except the simple mixing of the metal, resulting from
374 pouring it from the crucibles into the mixing vessel. I did this as long ago as 1869, and from thence through the years following up to 1873.

Complainant's counsel objects to this answer as irresponsive, and protests against the continual refusal of the witness to define his answers to a reply to the questions as put, although repeated protest in this regard has already been made by complainant's counsel.

Complainant's counsel further calls attention to the fact that the Lehage patent states: "In all cases the process must be continued

till the molten steel and the steel or iron added in the intermediate furnace is overmelted or superheated and the mass has become uniform," and that the personal experience of the witness being inconsistent with this paragraph is here irrelevant.

X Q. 91. Which of the prior patents described in your direct examination were put into use and practiced as described therein, prior to the invention of the patent in suit?

Objected to as wholly immaterial under the statute.

A. I have never seen any of the patents except that of Jones practically worked. There are a number of printed publications in evidence in the case that indicate to me that as I have already testified, the ideas involved in the process of Jones were well understood in the art of steel-making, long prior to his invention, and in the printed publications there are a number of instances described in regard to which I have already testified, in which these ideas were practically carried out.

All except the first sentence of the answer is objected to as incompetent and irrelevant.

X Q. 92. Which of the several prior patents in your judgment, most nearly and fully describes the methods of Jones, as stated respectively in the first and second claims of the patent in suit?

375 A. I will refer to the Deighton English patent, the Abel-Durfee English patent, the two United States patents of Witherow, the patent of Anton Lehage, the British patent of Bessemer. Those names are what occur to me at this moment.

X Q. 93. Which one of these most clearly and fully describes the subject-matter of claim 1? And which one most clearly and fully describes the subject-matter of claim 2?

A. The Deighton patent and the Abel-Durfee patent, in my judgment describe substantially what is claimed by Jones in his claims 1 and 2. It is difficult to state which describes it most clearly, but I should have no difficulty in carrying out the ideas of the processes described in the Deighton and Abel-Durfee patents, from the descriptions given in those patents. I regard the two Witherow patents as embodying substantially the same processes as those described in the claims of Jones. I should have no difficulty as a steel-maker in carrying out successfully the process described by Witherow. He sets forth a process which, if carried out, would, in my judgment, attain substantially the same results as that proposed by Jones. In the Lehage patent so far as the mixing of ununiform charges of metal is concerned, and obtaining an equalized and uniform charge is concerned, the idea of the process involved is substantially the same as that claimed by Jones. In the other patents and publications referred to in my direct testimony, I believe I have clearly described what I regard as their relations to the process of Jones.

The answer is objected to as not responsive, and the last question is repeated.

X Q. 94. Question repeated.

A. The several patents which I have referred to in my direct testimony, and in my last answer, vary so much in detail, while involving substantially the same idea, that it is difficult for me to state specifically just which patent is the most like the inven-
376 tion described in the patent in suit. I think my testimony is sufficiently clear and explicit to give an intelligent idea of my views relative to the various patents in regard to which I have testified.

X Q. 95. Question repeated. If it is impossible for the witness to state which most nearly resembles the patent in suit, he should say so. The mere statement of difficulty does not excuse an answer?

A. I should say the Abel-Durfee patent and Deighton patent were as near in their ideas and operations to the process described in the patent in suit, as any patents in regard to which I have testified.

X Q. 96. Which now of these two patents, in your judgment, the more fully and clearly describes the subject of claim 1 of the patent in suit, and which the subject of claim 2?

Objected to as already covered by the preceding questions and answers.

A. I do not know that there is much choice in the resemblance of the Deighton or of the Abel-Durfee patent to the patent in suit. In the Deighton patent the process described would be covered by claim 1, and also by claim 2; that would also be true of the Abel-Durfee patent.

X Q. 97. Question repeated. Complainant's counsel states that the mere fact that there is not much choice is not sufficient to excuse an answer to the question.

A. I cannot answer the question any better than I have already answered. I have stated that the Abel-Durfee patent and that the Deighton patent were practically the same, in idea and operation, as the patent in suit; and on the principle that things that are equal to the same thing are equal to each other, I do not see that I can indicate any choice between the Deighton and the Abel-Durfee patents.

X Q. 98. Then do you think it would be quite just to judge of the novelty of the Jones method solely by comparing it with the Abel-Durfee patent?

Objected to as incompetent and improper.

377 Complainant's counsel here states that if an instructing objection is to be given it should be written out and not stated in the hearing of the witness, and he asks that this course be followed.

The witness is instructed by counsel for defendant that he is at liberty to answer in his own way as to his opinion of what should be considered in determining the novelty of the Jones method.

A. In determining the novelty of any invention that of Jones or any other, I am clearly of the opinion and firmly of the belief that

the whole state of the art as it existed at the time and prior to the time of the issuance of the patents under investigation, should be considered in determining its novelty. That it would not be fair to the inventor or to any other parties to confine the comparison of the patent, to any special or particular apparatus or invention that was known and understood in the art prior to the issuance of the patent in suit. In order that the ends of justice should be attained I fully believe that the patent in suit should be compared with the state of the art to which it relates, as it existed and was practically carried out prior to the issuance of that patent.

Adjourned by agreement of counsel to Thursday, at 10.30 a. m.

THURSDAY—10.30 a. m.

Met pursuant to agreement.

X Q. 99. Did you know Mr. Z. S. Durfee, the patentee of the British patent which has been admitted in evidence, and to which you have referred?

A. I did.

X Q. 100. At the time of taking out his British patent was Mr. Durfee a well-informed metal-urgist?

A. I so regarded him.

X Q. 101. Do you believe the recitals in his British patent were true, with regard to the history of the art?

A. I do.

378 X Q. 102. You have quoted from a paper of Mr. Z. S. Durfee. Do you understand that the apparatus to which Mr Durfee refers was the apparatus described in his patent?

A. The apparatus described in Mr. Durfee's letter I regard as substantially the same as that described in his patent.

He describes in both letter and patent, the use of a reverberatory furnace, in which metals can be received, held and treated, in any desired way, before any portion of them is run into the converter for conversion into steel.

X Q. 102½. In this connection, state what is the meaning of the word "reverberatory."

A. The word reverberatory as applied to a furnace *and* indicates that the furnace is so constructed that the heat therein is reverberated, or thrown back from its walls and roof, upon the metal in the bottom of the furnace.

X Q. 103. Do you understand the operation of the defendant's mixing apparatus and method?

Objected to as not in the line of cross-examination, witness not having been interrogated on this subject.

A. I have never seen the mixing apparatus of the defendant; that is it has been described to me, and I have seen a model of it.

X Q. 103½. Have you read the description of it in the testimony in this cause?

Same objection.

A. I am not certain that I have read the description. Some time since I read some of the testimony in the cause, but at this moment I am not able to say with precision that the testimony that I read embraced a description of the defendant's apparatus.

X Q. 104. You have stated that in the use of the apparatus of Witherow gases migh rise from the metal and be consumed by an air blast from the tuyeres. Do you mean to say that you re-
379 gard this as a common-sense, practical way of heating the metal and keeping it heated, or that Witherow meant to do any such thing as that?

A. I have no doubt that with many irons such an action as I have suggested would take place, and I have no doubt at all that any practical metal-urgist using an apparatus like Witherow's would not employ any means to check the heating action that would result. This action is not by any means unknown in the treatment of cast iron. In its manufacture into wrought iron and steel, gases of a combustible character always separate from the iron and burn on its surface, and aid materially in maintaining its temperature in puddling furnaces, in which wrought iron is produced from fluid cast iron, and in which puddled steel is produced from cast iron.

X Q. 104½. You will please note that you have not at all answered my question, which had no relation to puddling furnaces, but was intended to get your opinion as to whether the heating of the metal in Witherow's apparatus solely by the gases rising from the metal and burned with a cold-air blast, is a common-sense, practical mode of heating that apparatus, or is one which Witherow intended.

A. There are various standards of common sense. Some of these standards would be recognized as reliable by one person and as very unreliable by others. Therefore it is impossible for me to say whether this suggestion is a common-sense method or not. I have no means of knowing, except from the description of Witherow's apparatus, what his intentions were; but if Witherow was an experienced metal-urgist, as I suppose he was, I have no hesitation in saying that if he wished to heat his metal in his receiving vessel, he would naturally avail himself of any convenient means of producing heat, which the working of the apparatus would enable him to make use of.

X Q. 105. Please give me a direct answer to the question,
380 and in answering it apply that standard of common sense which you are accustomed to use in the conduct of your own metal-urgical business.

A. I have already stated what I believe would occur under certain circumstances in the use of Witherow's apparatus; and if I were using that apparatus and should desire to maintain the heat of the metal within it, I should think I was destitute of the very commonest kind of sense if I didn't use all the means of maintaining the heat in the vessel that were conveniently available.

X Q. 106. You have not yet answered my question.

A. I believe I have fully answered the question.

X Q. 107. Which one of the several publications to which you have referred in your direct examination, most fully and clearly,

in your opinion, describes the process and apparatus of the patent in suit?

A. At this moment I do not feel qualified to state which one of the publications most fully describes the patent in suit, for I have not read those publications with a view to determine which is the most exact and precise description of the patent in suit. I have read those publications with a view of determining their general character, and whether they set forth and disclose practically the same process as described by the patent in suit; and I beg to refer to my testimony in regard to them, as already given, for my views. I do not believe that in order to determine with justice the question of the originality of the invention disclosed — the patent in suit, that it is at all necessary or just that any exact and precise resemblance of one reference or one description over another, as regards anticipating descriptions or publications, should be cited. I think it quite sufficient that the general resemblance of the details and methods of the various anticipating descriptions and publications to the patent in suit, should be stated.

X Q. 108. Will you now, Mr. Durfee, please answer the question, as you suggest, you have not as yet read the publications with
381 sufficient care, to warrant you in expressing your opinion on this point, I am quite willing that you should take such length of time for deliberation as you may desire, for I have no wish to hurry you.

A. I have read the various publications in regard to which I have testified with sufficient care, as I believe, to justify all the statements and conclusions which I have made in regard to and drawn from them. As I stated in my last answer, my purpose in reading those descriptions was not with a view to determine that description which most clearly resembled the process set forth by the patent in suit; and I do not see that the ends of justice would be attained by my stating as a result of any further examination, which description most nearly resembles the process set forth in the patent in suit. And therefore, I must decline to undertake the re-reading of the publications referred to.

X Q. 109. I must insist, Mr. Durfee, upon your giving a direct answer to my question, and I beg to remind you that your obligation as a witness requires you to deal as frankly and willingly with my questions as you did with the questions put by defendant's counsel. You read the publications for the purposes of his questions, and I must insist that you shall read them for the purposes of any relevant question which I may see fit to put. I therefore repeat the question.

Objected to as having been fully covered in witness' answer to question 93, and answers immediately thereafter; and further as being manifestly vexatious, the witness having explained at length in his answer, particularly in answer 97, why he cannot say that one publication is a more exact description than another of the method set forth in the Jones patent.

Complainant's counsel submits that the objection just made by

defendant's counsel is incorrect in point of fact, as will be seen by reference to the testimony to which reference is made.

382 A. The implication of the counsel in the questions that I have simply read these publications for the purpose of answering the questions proposed by defendant's counsel is a mis-statement of the fact. I have read these publications for the purpose of telling the court what I believe to be the truth in regard to them, and I have no disposition to do other than to carry out honestly, fairly and honorably that purpose. I fully believe that I have done so thus far in my testimony. I fully believe that the answers that I have already given to the question proposed are ample and sufficient, and for that reason I decline to make further reply.

In view of the refusal of the witness to answer the question which it is submitted is a very proper question, being one that is usually put to an expert witness in every patent litigation, for the purpose of directing the attention of the court and counsel to fullest and best illustrations of the prior state of the art, complainant's counsel gives notice that at the hearing he will move to strike the testimony of the witness from the record.

X Q. 110. Have you seen, and if so, when and where have you seen the stopping of the flow of metal from a blast furnace or reverberatory furnace, or any externally stopped reservoir of 50 or 100 tons while running under full head? For the purposes of this question, you may assume that by full head I mean after say 5 tons has been tapped from the original contents of 50 or 100 tons.

A. I have never seen any furnace containing 50 tons or 100 tons of metal stopped from the outside after the withdrawal of 5 tons.

Redirect examination by Mr. DODGE:

Q. 111. You have never visited the works of either of the defendants since the installation of the intermediate vessels, have you, when in operation?

A. I have not.

383 Q. 112. Are you informed in any way as to the character of the ores, the pig metal or the fuel used by either of the defendants, or as to the expense of the various operations in their works?

A. I am not.

Q. 113. Is it not a fact, then, that your opinion expressed in answer 26, that the blast-furnace metal would give a better mixture than their cupolas, was expressed without any definite data regarding defendant's works, on which to base it?

Question is objected to as manifestly improper. The answer was given as a matter of opinion, but so has the entire other testimony of the witness been given as a matter of opinion.

A. The answer was given without any definite knowledge of the actual facts existing in defendant's works.

Q. 114. In answer 31 you have referred to a method of stacking metal pigs to facilitate the mixing in the cupola. Say, if you know, whether this is the general practice prevailing in America.

A. I do not think it is.

Q. 115. In blast-furnace practice is it a fact or not that the quality and uniformity of the metal produced from the same ores and with the same fuel will vary considerably according as the furnace is skilfully or unskilfully handled?

A. It is a fact that the quality will vary if the furnace is not run with uniform skill.

Q. 116. You have spoken of metal being too high or too low in silicon for the Bessemer practice. Is there any exact or precise percentage of silicon demanded or used in the Bessemer process?

A. There is no exact percentage of silicon required or demanded, but it is preferable that the silicon should not be either in excessive amount or absent altogether.

384 Q. 117. In answer 44 you have described a reverberatory furnace. Of how large capacity are these furnaces known in the art?

A. They are built of all sizes. I have built them to hold less than a ton of metal, and I have built them to hold 10 tons, and I have seen furnaces that I was told would hold 40 tons.

Q. 118. In the Jones patent in suit reference is made to two vessels in either of which his mixing may be effected—one a charging ladle, the other his vessel 2. What is the usual capacity of the charging ladle as generally used in the United States in the Bessemer practice at the time of the Jones invention, and what the capacity of the vessel 2?

Complainant's counsel asks that the question be made more specific by stating which of the two kinds of charging ladle mentioned by the witness in the cross-examination, is meant.

Counsel for defendant replies that the question refers to the capacity of the charging ladles such as were commonly used in the United States at the time of the Jones invention, irrespective of the form.

A. The charging ladles used at the time of the Jones patent were sufficiently large to hold a single charge of metal for the converter, in connection with which they were used, say from 6 to 10 tons, and the vessel 2 in the Jones patent, he says may be made of any convenient size, holding, say, 100 tons of metal.

R. D. Q. 119. Referring to your description of the Deighton apparatus, please say whether the casting ladles 1 are generally made of the exact capacity of the converter charge.

Objected to as irrelevant and without proper bearing upon the patent of Deighton, which, furthermore, is a British patent, and witness has not qualified himself as familiar with the apparatus used in the locality in which Deighton resided.

385 A. Casting ladles are usually made larger than is necessary to hold the exact weight of the metal contained in the

converter. In pouring the metal from the converter into a casting ladle, there is always more or less cinder runs out into the ladle and floats upon the surface of the metal. It is customary to make the ladle large enough to accommodate easily both metal and cinder.

R. D. Q. 120. In your cross-examination you corrected certain relative measurements of the casting ladle and receiving vessel shown in the Deighton drawings. Please say whether in the light of your last measurements, the receiving vessel *m* was the larger or smaller of the two in capacity?

A. The receiving vessel was very much larger than the casting ladle.

Recross-examination by Mr. BAKEWELL:

R. X Q. 121. What was the general practice of selecting pig metal for melting in cupola furnaces in this country at the date of the patent in suit?

A. The metal was usually received at the Bessemer works upon cars. These cars were unloaded promiscuously and the metal was thrown from them into large piles of irregular dimensions, and from these piles of pig iron, the metal was taken to the cupolas for remelting.

R. X Q. 122. Will you please tell me at what Bessemer works, at the date of the Jones patent, this haphazard method was practiced?

A. I have seen piles of pig metal at the Edgar Thomson works and at other works that I have visited, but I am not able to state now exactly what other works in which I have seen this practice; but as soon as the product of the Bessemer steel works reached a very large amount per day, and the necessity for rapid handling of the pig iron used was pressing, the method I have named which counsel calls a haphazard method, was adopted. I think it has been used in a number of works I have visited. The Cambria
386 works, the Pennsylvania steel works, and the Bethlehem works. In each of these works I believe this so called haphazard practice was in regular use.

R. X Q. 123. Do you mean that you know it of your own observation and knowledge and that you so testify?

A. In regard to the last named works, I mean this: I have seen piles of pig iron, such as I have described; I have seen iron in process of unloading from the cars, and I have been told at some of these works that those piles of iron were intended to use for the cupolas of the Bessemer works. I believe it to be a matter of common knowledge among metal-urgists that this so-called haphazard method of selecting pigs for remelting was generally practiced.

R. X Q. 124. Was it not usual in buying Bessemer pig metal, to have the metal supplied according to specification, both as to chemical and mechanical condition?

A. I should say that that was the general practice.

R. X Q. 125. And when Bessemer works used pigs taken from its

own blast furnaces, was it not customary to select the pigs in a similar manner with reference to their chemical and mechanical condition, for charging into the converters?

A. I think the iron used in blast furnaces operated in connection with Bessemer works was frequently examined by the chemists of the works to ascertain its character.

R. X Q. 126. Does not the quality of pig metal from the blast furnace, vary frequently on account of changes of the weather and unknown causes?

A. Blast furnaces are liable to work irregularly and their product is liable also to irregularity.

R. X Q. 127. Is there not a minimum and maximum percentage of silicon in Bessemer pig metal, which cannot be varied from substantially without deteriorating the product? I mean, of course, that you should answer the question with reference to metal in which no other element is added to take the place of the silicon.

387 A. I have already testified that it is desirable that some silicon be present in pig metal used for the making of Bessemer steel; but that it is not desirable to have an excessive quantity. It is difficult to state what would be regarded as a standard limit of silicon for all works under all conditions. The peculiarities of the working of some establishments would admit of a larger amount of silicon than would be admissible in works run under other conditions.

R. X Q. 128. Please answer the question directly.

A. To further explain my answer, I will say that in a works using a given percentage of silicon, and operated in a certain way, a certain quality of steel will be produced; in another works operated in a different way, they might use a pig metal containing a different proportion of silicon, and produce steel of an equally good quality with that produced in the works first supposed.

WILLIAM F. DURFEE.

Testimony of Robert Forsyth.

Robert Forsyth, a witness called on the part of the defendants, being duly sworn, deposes as follows in answer to questions put to him:

Q. 1. State your name, age, residence and occupation.

A. Robert Forsyth, age 46; residence, Chicago, Ill.; occupation, consulting engineer.

Q. 2. Are you a graduate of any school or college of engineering, and if so, what kind?

A. I am a graduate of Rens-el*l*aer Polytechnic, Troy, N. Y.; graduated in the class of '69.

Q. 3. What experience, if any, have you had in connection with the manufacture of Bessemer steel? In answering this question, please state times and places and positions held by you, so as to show your experience in this regard.

388 A. I began my experience in steel in learning the process at the Troy steel works in 1870. This experience was under the late A. L. Holley.

Q. 4. How long were you there?

A. I was there two years, and then took charge of the new Bessemer works of the North Chicago Rolling Mill Company in Chicago. I remained there from 1871 to 1883, during which time I had charge of their Bessemer department, and designed, constructed and operated their new Bessemer works at South Chicago. Since that time, I have been successively manager of the Union Steel Compay, now part of the Illinois Steel Company. Since 1889, when the Illinois Steel Company was organized, until June, 1896, I have been chief engineer and second vice-president of that company. From 1883, when I left the North Chicago Rolling Mill Company up to 1885, when I went to the Union, I was superintendent of the Spang Steel & Iron Company, Pittsburgh, and practiced as consulting engineer in Chicago.

Q. 5. What kind of steel was manufactured at the different works to which you referred?

A. The North Chicago rolling mills made only Bessemer steel; the Union Steel Company made only Bessemer steel; the Spang Steel & Iron Company made only open-hearth steel, and the Illinois Steel Company has made both Bessemer and open hearth. Open hearth since the 1st of February, 1895.

Q. 6. Did any of the mills to which you have referred employ blast-furnace metal for conversion, while in the molten condition, as drawn from the blast furnace?

A. Yes, the South Chicago works of the North Chicago Rolling Mill Company were built and started as a direct metal plant; no cupolas were put up at this plant for some time after they started. The Joliet works of Illinois Steel Company also used direct metal to some extent.

389 Q. 7. Please state about when the South Chicago works commenced operations in Bessemer steel, by the employment of direct metal, and state the practice of working at that mill.

A. The South Chicago works began in June, 1882, with four blast furnaces and three converters. Their practice was to use metal direct from the blast furnaces. In carrying out this process, ladles holding twelve to fifteen tons were charged at the furnaces with molten metal and transported by rail to the Bessemer works, where they were successively poured into the converters and blown. As a rule ladles were filled by estimates to the proposed weight at the furnaces and taken direct to the converter, but it was sometimes the practice to partly fill ladles at one blast furnace and complete the filling with iron from other blast furnaces. After cupolas were erected, which was in 1884, it was often the practice to partly fill ladles at the blast furnace and complete them with iron from the cupolas. Though I was not connected with the active management at that time, I saw it done, and subsequently, when I was in charge as an officer of the Illinois Steel Company, I saw it when it was under my charge.

Q. 8. In taking the metal from the blast furnaces how were you guided as to this matter of taking the converter charge from one blast furnace or two blast furnaces, or adding cupola metal as you have stated?

A. When any blast furnace or furnaces were known to work badly or making iron high in silicon, which can be determined by the appearance of slag, etc., in ways well known to furnace men, it was the custom to mix the iron from such furnace with that from other furnaces, or from the cupolas for the purpose of procuring a mixture proper for conversion.

Q. 9. In the operation of this plant, South Chicago, with direct metal, how successful was it in the production of steel of practical uniform quality?

390 A. The works were as successful in this respect as any works with which I was acquainted at that time, whether the metal converter was cupola metal or blast-furnace metal, considering the difficulties of starting the new plant, the first one to use direct metal regularly in this country.

Q. 10. How long did these works continue to operate employing direct metal in the way you have described?

A. For 10 years from 1882 to 1892, at which time the mixer or reservoir was installed.

Q. 11. Was there any difficulty in operating in this way with the direct metal such as practiced for ten years, and if so, what was it?

A. The principal difficulty, the difficulty which finally decided the Illinois Steel Company to put in a mixer or reservoir was the greatest variation in weight of the molten metal from the blast furnaces delivered to the converters in the manner I have described.

Q. 12. How did this arise?

A. It arose from the impossibility of accurately filling the ladles at the blast furnace.

Q. 13. What objection was this in practical working?

A. There would be delivered to the converters sometimes a heat of metal of excessive weight and sometimes one of short weight. This would make the regulation of the temperature of the blow difficult and involve difficulties in the amount of recarburison, as well as produce sometimes short ingots and sometimes an excessive amount of scrap in ingot form.

Q. 14. Was this overcome by the mixer or reservoir and what was the principal advantage in its use?

A. This difficulty was entirely overcome by the use of the reservoir or mixer, and, in my opinion, this is the chief advantage of such reservoir.

Q. 15. What other advantage did the reservoir give in practice?

391 A. It provided a place of storage for molten metal to be drawn upon by the Bessemer works as wanted, and to be filled from the furnaces as circumstances made necessary, making the blast-furnace plant and the Bessemer works in a measure independent of each other. Another incidental advantage was, that to

a certain extent, mixture of metals took place in the mixer, giving a better average of metal for conversion.

Q. 16. Taking the cost of carrying the metal from the blast furnace to the converters, which is the more economical per ton, the carrying of the metal direct from the blast furnaces to the converters, or the introduction of the metal into the mixer or reservoir and the carrying of that metal to the furnace?

A. Considering the metal as simply delivered to the converters the cost of operation would be less without the mixer than with it, because of the cost of running the mixer itself, fuel, supplies, etc. The principal advantage of the mixer was in getting accurate weights for the converter.

Q. 17. Was there a saving in the cost of making the Bessemer steel in using the metal direct as compared with the casting of metal into pigs and remelting pigs in cupola?

A. There was undoubtedly a saving by the use of direct metal, but I am unable to state what the saving would be or was. It would arise from the saving of labor and of fuel required for remelting the pig iron in cupolas.

Q. 18. Mr. A. M. Moreland, a witness for the complainant, testified that there was a saving of an average of 65 cents per ton of ingots produced between the Jones mixer process and the cupola process. He was then asked:

"Q. 4. Please give us an itemized statement of how this saving takes place.

A.—

By saving in loss of metal in melting in cupola and blowing in converters	25c. per ton
Labor at cupolas	20c. per ton
Expenses, repairs and supplies	5c. per ton
Coke and limestone	15c. per ton

These figures make up the 65 cents."

392 Please state whether any of these expenses would be incurred in using direct metal, such as you have described in connection with the practice at South Chicago in 1882 and subsequently.

A. None of these expenses would be so incurred.

Q. 20. Have you examined the patent granted to William R. Jones, June 4th, 1889, No. 404,414, for the method of mixing pig metal on which suit is brought, and do you understand the invention set forth therein?

A. I have examined the patent and believe I understand the invention set forth.

Q. 21. As a metallurgical engineer and a practical steel manufacturer having had experience in this particular art, will you please state what you understand to be the supposed invention set forth in said patent?

A. I understand the invention to be a process of mixing dissimilar portions of molten metal to obtain an average quality of metal for subsequent treatment.

Q. 22. Do you understand the invention to be limited to the treatment only of blast-furnace metal, or metal taken directly from the blast furnace and treated without remelting?

A. I understand the invention to be applicable to molten metal, whether obtained from blast furnaces or by remelting.

Q. 23. Is there any practical difference between blast-furnace metal which is used without casting into pigs and introduced into the converter or subjected to other refining means, and metal which has been cast into pigs and remelted for like purpose?

A. There is no such difference between metals of like chemical composition; in both cases both metals are properly known as pig metal and contain the same substances in combination or solution, such as carbon, silicon, sulphur, etc.

393 Q. 24. In examining this Jones patent, do you understand that the mixing described therein can only be performed in a large receptacle, such as is illustrated in the drawing of the patent, or can it be performed in any different receptacle?

A. I see no reason why it may not be performed in a receptacle much smaller than that shown; in fact, the specification itself mentions carrying out the invention in a charging ladle, which is a ladle used for conveying the molten iron to the converters. A charging ladle as used about the time this patent was obtained would be a ladle mounted on trunnions and adapted to pour into the converter the molten iron contained in it. Depending upon the nominal size of the plant, these ladles would have a capacity of from ten to twenty tons.

Q. 25. Do you understand the invention to refer only to the mixing of metals from different furnaces?

A. No, I understand the patent to refer to the mixing of metals not only from different furnaces, but from the same furnace at different times, and even the same cast of a furnace—even mixing the different parts of a single cast from one furnace.

Q. 26. From your practical knowledge of steel-making and the use of blast furnaces, would there be any difference in the chemical composition or proportions of ingredients in different parts of the same cast?

A. There would be such differences. It is not uncommon, in fact, it is well known to blast-furnace men that the first iron of a cast, that flowing first out of a furnace, may be and often is of very different composition from the last which flows out of the same cast. This difference is especially noticeable in the matters of silicon and sulphur.

Q. 27. Please refer now to the claims of the patent. I ask you to do this as a practical engineer. Look at the first claim of the patent and state what the steps set forth in it are, as you understand it?

A. In carrying out the process as shown in the first claim 394 I should say that a charge of iron direct from the blast furnace should first be thoroughly commingled to secure a better average quality and subsequently refined.

Q. 28. So far as the refining step of this claim is concerned, is that in any way a novel step in the treatment of pig metal?

A. No; it is not novel; it is the usual Bessemer operation.

Q. 29. You described the employment of direct metal at the South Chicago works as practiced under your supervision from 1882 to 1883 in which metal was drawn from two different blast furnaces into a ladle to make up a complete converter charge. What bearing has such practice upon this first claim of the Jones patent?

A. I should say that such practice embodies the entire method of the first claim. The metal was metal direct from the blast furnace; it was taken from two different furnaces and was mixed by being poured into one ladle. It was then taken to the Bessemer works and subjected to the usual Bessemer operation.

Q. 30. I call your attention in this connection to the Journal of the Iron and Steel Institute, published in 1871, pages 400 to 416, containing an article by Mr. E. Kohn, "On the production of alloys of irons and manganese and their applications to the manufacture of steel," describing the practice at Terre Noire. Please state the bearing of the practice at Terre Noire, as so described, upon this first claim of the Jones patent as you view it from the light of a practical engineer?

A. I find the practice at Terre Noire described as follows: "The ladle is brought to the back of one furnace and half filled; it is then run to the next furnace and filled up. In this way the Terre Noire Company always obtain a mixture of the metals and therefore the greatest regularity is secured through the rest of the work."

395 This seems to be the process set forth in the Jones patent, as the metal from two different furnaces is mixed in the same ladle and subsequently refined.

Q. 31. Now, please look at the second claim in this patent and consider it in the light of a practical steel-maker, and state, first, as to what metals you understand are included in the scope of the claim for treatment.

A. The claim says: "In the art of mixing molten metal to secure uniformity of the same, etc.," by which I understand, "molten metal," however obtained, whether direct from the blast furnace or remelted.

Q. 32. As a practical steel-maker, will you please state whether the term "molten metal" as understood by Bessemer steel manufacturers has any distinctive meaning.

A. The term "molten metal" has no special significance in steel and iron making, and would be taken to mean metal in a melted state, however obtained.

Q. 33. What terms are generally used to distinguish blast-furnace metal and metal obtained from cupolas?

A. Metal used direct from the blast furnace is called "direct metal," sometimes "furnace metal;" metal from cupolas is always known as "cupola metal."

Q. 34. What are the steps of treatment of this molten metal set forth in the second claim as you understand it as a practical steel-maker?

A. I understand that under this claim the molten metal in successive portions would be run into a mixing receptacle from which

portions of the contents would be drawn from time to time without entirely emptying the vessel, and that it would be from time to time replenished with fresh additions.

Q. 35. I call your attention to the English patent of William Deighton, No. 3672 of 1873, and ask you as a practical steel-maker to state the bearing this patent has, in your opinion, upon the method described in the Jones patent.

396 A. I should say that the operations set forth in Deighton's patent embodies the operations set forth in the Jones patent. My reasons for this statement are that this patent shows a receptacle adapted to receive metal from two or more blast furnaces which receptacle is placed upon a weighing machine, and from it, from time to time, portions of molten metal are drawn as required for use. The receptacle would be refilled from time to time from the furnaces as it became necessary to tap them and would provide a reservoir for the supply of the Bessemer converter. It is evident that mixture of metal from the blast furnace would take place in Deighton's receiver, and in fact, the claims or specifications state that the receiver *m* forms a receptacle for mixing the molten metals from two or more of the smelting furnaces.

"From the receiver *m*, the mixed molten metal is tapped, and flows down the swivel through *n*, into the converter *a*. By placing the vessel *m* on a weighing machine it can be readily ascertained when the exact quantity required has been tapped from it into the converter."

This is specifically set forth in claims at the end of the patent, as follows:

"Sixthly. The system or mode of arranging and working Bessemer converters with a receiver or receptacle *m*, for mixing the molten metal from two or more smelting furnaces to get a more uniform quality of metal."

Q. 36. What is there in the patent to show whether this mixing receptacle is entirely drained or not when the metal is tapped therefrom into the converter?

A. This would seem to be settled by the language of the specification in saying, that the vessel *m*, is placed on a weighing machine and it can be readily ascertained when the exact quantity it required has been tapped from it into the converter. It would seem from this that it was contemplated to maintain a body of metal in the receiver from which charges of specific weight for the converter would be drawn if needed. It would obviously be impossi-

397 ble to tap a predetermined weight of metal from each of the blast furnaces into this receiver, and this I think is also made clear by the statement of the specification, saying:

"My invention also consists in taking the molten metal directly from the blast furnace to the converter, in which case I prefer to arrange the Bessemer plant * * * and place a vessel to receive the molten metal tapped from two or more blast furnaces to get a better average of metal which would be more suitable to making Bessemer steel or metal of uniform quality, the vessel or receiver being placed on a weighing machine so that any required

weight may be drawn or tapped from it and charged into the converter."

The object is to get a mixture of metal, or metal of a uniform quality which will be suitable for conversion, and this taken with the idea of weighing it in this vessel indicates to my mind clearly that the vessel is to receive the metal from the furnace and hold it there ready to be tapped out.

Q. 37. Are you accustomed to calculate the cubical contents of vessels for holding metal; and, if so, have you examined the drawing of this Deighton patent to ascertain about what the relative holding capacity of the receiver *m* would be as shown by the other parts of the drawing?

A. I am familiar with such calculations, and figured the capacity of the receiver *m*, on the supposition that the drawings represent a Bessemer plant of say ten tons nominal capacity of the converter. I find that the capacity of the receiver would in this case be over 400,000 lbs., allowing for the proper thickness of lining and bottom.

Q. 38. In your description of the South Chicago plant you referred to the advantage of the use of a receiver as a means for weighing the metal for the converter, so as to make the blast furnaces independent of the converter plant. Would these advantages be obtained with the apparatus according to the method described in this Deighton patent?

A. Yes.

398 Q. 39. I see that the receiver *m* of this Deighton patent is a stationary receiver not arranged to be tilted. Could, in your opinion, a proper mixture so as to obtain an average thereof be accomplished in such a receiver?

A. I see no reason why such mixture should not take place as well in the Deighton receiver as in the Jones mixer. In both cases there would be a mixture made by the pouring into the receiver of the molten metal, and this is practically all the mixture that takes place in any form of mixing vessel.

Q. 40. I call your attention to the United States patent to James P. Witherow, No. 315,587, April 14th, 1885, and ask you as a practical engineer and metal-worker as to what bearing this patent has upon the method of the Jones patent?

A. I find in the patent you referred to a receptacle interposed between the blast furnace and the converter to receive iron from the blast furnace and store it for use in the converter. This receptacle is preferably constructed to take a whole cast from the blast furnace, but may be used with a smaller quantity. If the entire charge were taken from the blast furnace there would be a mixture of the varying qualities of metal in the hearth of the furnace in this receptacle, and in the operation — the patent this metal would subsequently be converted.

Q. 41. I call your attention to United States patent to James P. Witherow, No. 327,425, September 29th, 1885, and ask you as to the bearing this patent has upon the method of the Jones patent in suit.

A. This patent appears to be an improvement upon the other Witherow patent and describes a receptacle of sufficient size to hold the entire cast from the blast furnace, provided with a cover and a series of tap-holes from which the metal may be tapped into a charging ladle standing below it. This charging ladle is intended to convey the charge to the converter. Proportionate sizes of blast-furnace hearth and of the receptacle as shown on the draw-
399 ings indicate that a large receptacle was intended to be used. Inasmuch as the receptacle will hold at least an entire cast, it is evident there would be a mixture in the receptacle of the portions of the cast flowing successively from the furnace hearth. It is also evident that unless the metal was taken from the receptacle with sufficient rapidity to empty it between the time of furnace casts that a second cast would be mixed with that already in the receptacle. In Bessemer operations delays are constantly occur-ing which would make this mixture of two or more successive casts from the same furnace take place necessarily.

Q. 42. I call your attention to an article in the Journal of the Iron & Steel Institute for the year 1874, pages 348 to 367, entitled "American rolling mills," by Mr. Alexander L. Holley, which also contains a discussion on the subject of Bessemer steel manufacture, and would ask you to state as a practical steel manufacturer and engineer the bearing of this article upon the method described in the Jones patent in suit?

A. I find in the discussion in this paper mention made by several speakers of the use of direct metal in the Bessemer process. I find a considerable difference in the views of different speakers as to the value of direct metal and the way in which it is used at different works, but I note that Mr. E. Windsor Richards mentions the Terre Noire practice of mixing iron from two blast furnaces in the same ladle, to which I have already referred. Mr. Snelus also agreed that there was no insuperable difficulty in running iron direct from the blast furnace to the converter, but he proposed to overcome such difficulties as presented themselves—

"By running it into a separate vessel as they did in America, they could then deal with it as they liked. The plan in all the works in America was to melt in a cupola continuously, and then to run the iron into a ladle, which was balanced and held from 10 to 12 tons. From that the six-ton charge was run direct into the converter. They wanted an intermediate vessel between the blast furnace and the converter."

400 This would seem to show that in 1874 the plan of mixing of either cupola or blast-furnace iron in a ladle was understood and proposed, the one being understood as practiced in America with cupola, and from this the suggestion being taken of its use with blast-furnace metal. This intermediate ladle between the blast furnace and the converter would provide for the mixing of the metals in the same manner as described in the Jones patent.

Q. 43. I call your attention to the article in the Journal of the Iron and Steel Institute of 1876, pages 12 to 42 inclusive, entitled 'The use of molten iron direct from blast furnace for Bessemer

purposes," and to the discussion found in that paper, and would ask you to state what bearing this has, in your opinion, upon the *the* method of the Jones patent?

A. I find an extended discussion of the subject of the use of direct metal and remarks by Mr. Snelus, in which he says he did not think it advisable to take the iron from one furnace, "but they might get an average mixture by taking it from two. They found no difficulty in taking three tons from one furnace, stopping the furnace up again and going to another." Mr. Bessemer also said that his earliest idea was to employ molten metal direct from the blast furnace. He had himself "proposed the tapping of three furnaces into one ladle or receiver." He also said that certain parties had arranged their works—

"So that the pig iron could be tapped into a ladle, or rather in a spherical vessel with an almost closed top to it that would hold 20 tons. It was proposed to make at least 3 7-ton tappings into that vessel and to move it on wheels into the converting-house, using a pair of converting vessels, one after the other, until the four charges of five tons each were worked off; having a second ladle or vessel on its journey to supply, so as to keep on working continuously."

This appears to be a mixer on wheels and meets broadly the idea of mixing metal from the blast furnaces as described in the Jones patent.

401 Q. 44. I call your attention to an article found in the Journal of the Iron & Steel Institute for 1878, page 122 to 137, being a discussion of a previous paper on the manufacture of Bessemer steel rails at the works of Messrs. Brown, Bailey & Dixon, Limited, and ask you to state your opinion as a metallurgical engineer and practical steel manufacturer of the bearing of this article upon the Jones method in suit.

A. I find it stated in this article that Mr. Holley informed Mr. Snelus that at the Bethlehem works in this country Mr. John Fritz—

"Was doing half their work direct from the blast furnaces, and had for some time had under consideration the idea of a receiving ladle, so as to receive metal from the blast furnace, and hold it in readiness there for the converters. One great drawback to the direct casting process was, that you could not always get your metal at the exact time you wanted it. He believed it would be found that the great advantage the Bessemer works in America had, was the intermediate receiving ladle which was designed by Mr. Holley, and which was universally used there, although it was never used in England. The Moss Bay Company attempted to modify the thing some time ago, and put up a heating furnace, but that, to his mind, was a step in the wrong direction. Anyhow, the thing had failed, and no one in England, so far as he knew, was using any intermediate receiver between the blast furnace and the converters. He thought himself that the receiver was of considerable importance, both for saving time and facilitating the admixture of iron; and he was confirmed in that view by the idea of Mr. Fritz, of Bethlehem, who was about putting up a 30-ton ladle, ac-

cording to Mr. Holley, to receive the metal from the blast furnace, and hold it in readiness, so that at a moment's notice you could take your iron into the converter and also obtain a better mixture."

It would seem from these quotations that the advantage of the receiver in the matter of mixing iron and of storing it for use was fully appreciated in England in 1878, and described as being intended to be used by Mr. Fritz at Bethlehem, and it would
402 appear that the use of the intermediate receiving ladle in American works was considered in England to involve the advantages claimed for the Jones mixer. Taking the whole article quoted, to my mind, as a practical steel-maker, it seems to clearly indicate the intention to use the Bethlehem ladle as a storage ladle from which the metal could be drawn when needed and into which the metal was introduced from the blast furnace.

Q. 45. I call your attention to the practice of tapping metal from two blast furnaces into the same ladle and refining it in the converter as employed by you at South Chicago, and as described as used at Terre Noire. Will you please state what mixing or intermingling actually occurs in the converter in connection with the refining of crude metal?

A. Any metal introduced into the converter and blown would necessarily almost immediately become thoroughly mixed by the action of the jets of air forced through it from the bottom at considerable pressure. This action would probably produce as thorough a mixture as it is possible to get under any circumstances.

Q. 46. I call your attention to the article found in Engineering, volume 23, pages 183 to 184, being an article entitled "American iron and steel works, No. 1, by A. L. Holley and Lenox Smith." What bearing, in your opinion, has this article upon the Jones method in suit?

A. This article is a description of the Vulcan works at St. Louis, and I notice that the plant is so arranged that direct metal can be used. The blast-furnace metal is brought in in a ladle and raised by hydraulic lift to the level of the ladles in front of the cupolas, and the drawing shows arrangements for tapping iron from the three cupolas into this ladle of blast-furnace iron, as well as into the two cupola ladles proper. It is evident that these three ladles were intended to be used for storage purposes, for the article says:

403 "These three ladles will hold six vessel charges, which could be stored and converted when the converting department is ready for them. Cast iron will "live" in these thickly lined ladles, when covered with charcoal, for several hours; but it is necessary to put these ladles upon weighing machines, so that either uniform vessel charges may be run out, or so that the spiegeleisen may be proportioned to such charges as are run out."

Evidently the intention was to store melted iron in these ladles, keep it hot for several hours, if necessary, and to pour out from them weighed portions, as might be necessary, as well as to mix cupola and blast-furnace metal. The mixing of blast-furnace and

cupola metal in this case, seems to me to meet broadly the Jones mixing practice as described in his patent.

Q. 47. I call your attention to extracts from Jean's history of steel manufacture, published in London, 1880, pages 421 to 425 inclusive, being an account relating to the Rhymney steel works. Please state what bearing that has upon the method of Jones's patent in suit?

A. The article says:

"More uniform results being obtained by mixing the produce of two or more blast furnaces, this plan is followed here, with the means of taking a further supply of iron when required from the cupolas (two in number), which are situated alongside the subway leading from the furnaces to the steel works; they are used for re-melting the iron made, and run into pigs on Sundays or at such other times as the steel works may not be in operation, care being taken to use such iron in the cupolas, as will correct any irregularity in the iron taken from the blast furnaces, and thus secure the desired regularity in quality."

I find here a clear intention to mix molten metal from two or more blast furnaces and also a suggestion of mixing a further supply of iron from the cupolas. It seems even intended to correct anticipated irregularities in the blast-furnace iron by melting a particular kind of iron in the cupolas. This is stated to be done for
404 the purpose of securing regularity and quality, and would seem to meet all the points necessary to embody the practice with the Jones mixer.

Q. 48. Suppose a case of the manufacture of Bessemer steel in which pig metal is remelted in several cupolas, 3 to 5, and is run into a large receiver ladle holding, for example, 35,000 pounds of molten metal by means of a common runner leading from all the cupolas, which ladle is at times filled to hold its entire capacity, and from which converter charges any of from 14,000 to 17,000 pounds would be withdrawn at intervals as needed, leaving remaining in the ladle after withdrawing such charge from 5,000 to 20,000 pounds, and metal was again tapped from the cupolas into the metal so remaining, when they were ready for tapping, and the supply so kept up. What bearing would this practice have upon the method of the Jones patent if prior thereto?

A. I think the practice, as described, embodies the features of the Jones method. The metal as it comes from the cupolas is by no means uniform in composition, and the running of it into one ladle, as described, would mix successive portions of non-uniform metal substantially in the way described as the Jones method. Metal would also be stored in the receiving ladles, and weighed portions withdrawn from time to time and additions of fresh non-uniform metal made by further cupola tappings. Furthermore, I see no difference in these respects whether the metal as supplied to the ladle be metal direct from the blast furnace or cupola metal. In either case the metal would be "molten metal."

Q. 49. Suppose a case in connection with foundry practice for the manufacture of car wheels, that three cupola furnaces are employed,

which are tapped into a large ladle holding from 12 to 15 tons of metal, and from time to time small charges of about 600 pounds are withdrawn from this large ladle without entirely emptying the same, and the metal is subsequently tapped from the cupolas into the metal remaining in the large ladle. What bearing would such practice have upon the method of the Jones patent if prior thereto?

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A. I see in the practice described features which, in my opinion, embody the practice of the Jones method. Molten metal is received in a large receptacle stored there, withdrawn from time to time as needed, and the receptacle is replenished with fresh additions from the cupola. Undoubtedly mixture would take place of the metal tapped from each cupola in the first instance, and also of the metal remaining in the receptacle with that subsequently tapped in.

Q. 50. Were you acquainted with Capt. Wm. R. Jones, the patentee of the supposed invention in the patent in suit, in his lifetime?

A. I was intimately acquainted with Capt. Jones from 1871 to the time of his death.

Q. 51. How intimate was this acquaintance, how often did you meet him, and what subjects did you discuss with him? Please state this a little more fully.

A. We were accustomed to meet during this time at rather frequent intervals, paying each other visits, at the works managed by the other; and for a year while I lived in Pittsburgh; I saw him perhaps once a week. We were accustomed to discuss matters of interest in a metal-urgical and manufacturing way, and our acquaintance may be said to have been an intimate friendship.

Q. 52. Do you know whether Capt. Jones was acquainted with Mr. A. L. Holley in his lifetime?

A. He was. Their acquaintance was, if possible, even more intimate than my own with Capt. Jones.

Q. 53. During the time that you were connected with the manufacture of Bessemer steel, as you have stated, during the lifetime of Mr. A. Holley, were you also intimately acquainted with Mr. Holley?

A. I was. I knew Mr. Holley from 1870, about which time I worked under him at the Troy works, until his death in 1882. During this time I saw him frequently, both in his visits to the different steel works throughout the country, and at his house in Brooklyn.

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Q. 54. Have you any knowledge of the sending of articles or reports by Mr. Holley to the different steel works in connection with the manufacture of Bessemer steel during any part of his lifetime?

A. Mr. Holley made reports, especially as to foreign practice, from time to time, to the steel manufacturers of the country, and also sent copies of these reports to me personally, so that I was familiar with the subject-matter and his remarks on matters of interest in steel practice.

Q. 55. What attention was paid, to your knowledge, to these reports made by Mr. Holley of foreign or other practice in Bessemer steel manufacture, which were distributed as you stated?

A. They were always eagerly read and thoroughly appreciated by the parties to whom they were sent, and I know that they were always discussed and benefit derived from the information contained in them, and in my own case, I can say that I have frequently discussed the matters of *which* these reports with other steel-makers.

Q. 56. In what consideration was Mr. A. L. Holley held by the steel manufacturers of the United States?

A. Mr. Holley was held in the highest consideration and regard by the steel-makers throughout the country. Many of them had grown up under his tuition and had had the benefit of his advice and counsel. He was considered the foremost man in steel-making in this country. So highly was he esteemed that after his death a portrait bust was set up in Washington square, New York, by subscription of his fellow-engineers. Mr. Holley had been a member of many engineering and technical societies, such as the American Society of Mechanical Engineers, the American Society of Civil Engineers, the Institution of Civil Engineers of Great
407 Britain, the Iron and Steel Institute of Great Britain, and has been the president of the American Institute of Mining and Engineers. The American societies mentioned held memorial meetings after his death and published special records of the proceedings of these meetings.

Q. 57. I call your attention to a printed article entitled "The direct use of blast furnace metal and the Bessemer process," dated New York, June, 1877, marked copyrighted, 1877, A. L. Holley." Are you acquainted with this article, and, if so, how long have you known of it?

A. I am acquainted with the article and have known of it since its publication.

Q. 58. Have you had any occasion within the last few years to re-examine this article in connection with your work, and, if so, what led to such re-examination?

A. I had occasion to look up this article among others when I was designing the mixer for the South Chicago works of the Illinois Steel Co. in 1891. I remembered this article and the practice described in it and carefully re-read it at that time.

Q. 59. Why was this article brought to your recollection at that time?

A. Because I was occupied in designing a mixer, as stated, and I remembered to have seen this article containing some discussion as to mixing practice of that day.

Q. 60. Please examine this article and state how it bears upon the supposed method of mixing metals described in the Jones patent in suit.

A. The article is entitled "Direct use of blast furnace metal in the Bessemer process," and begins by stating that blast-furnace iron has been used direct in the Bessemer converter for a sufficient time in Great Britain to test its advantages and to show its incompleteness and also to suggest a remedy. It discusses fully the difficulties and then says:

"The obvious remedy is to mix a number of blast-furnace charges, so as to reduce the irregularity to a minimum. Two systems
408 of doing this are on the eve of trial. The one is simply mixing so few charges in a tank that the metal will be drawn out before it chills; the other is to store a large number of charges in a heated tank—that is to say, in an immense open-hearth furnace."

Mr. Holley then describes the early Bessemer practice in Sweden with direct metal, and also mentions the early English practice. Under the heading of "West Cumberland practice" he describes the general arrangement of the West Cumberland plant and the ladle carriage used for transferring the metal from the blast furnaces to converters. He then says:

"A vessel charge is tapped into a ladle from two furnaces always, and sometimes from three. The greater part of the charge is taken from the furnace which is making the most suitable metal, or, if one furnace is working hot and another cold, the manager draws the best mixture he can, due regard being paid to the proper relief and working of the furnaces."

Further on Mr. Holley says:

"In order to get a more uniform metal, Mr. Snelus is about trying the experiment of placing a 20-ton ladle on a hydraulic lift at the "A pit," so arranged as to store, mix and pour, say three 6-ton to 7-ton blast-furnace taps, or to mix blast-furnace and cupola metal. No doubt this body of metal will "live" if the ladle is thickly lined and well covered."

After stating the benefits which this practice will bring to the blast furnace, Mr. Holley says:

"Yet with all the care taken at Terre Noire and at Creusot, with manganese as a heating element, there is more or less trouble from the variation of the temperature of the charges. Ores will never be uniform; hence uniform results in the Bessemer department can hardly be expected, unless a number of blast-furnace charges are mixed. This would seem to be the theoretical solution of the problem."

Under the head of "Unfinished works," Mr. Holley describes the plant at Moss Bay as follows:

409 "The most unique Bessemer works I have ever seen is nearly complete at Moss Bay, a suburb of Workington. The vessels stand side by side and high, so that there is no pit. In front of them there is, not a ladle crane, but a high-jib hydraulic crane. This crane, by means of a yoke, lifts the ladle of iron to the vessel nose, and it also, by means of a yoke, holds the steel ladle under the vessel nose while pouring, and then transfers it to the ladle crane, which stands at one side. On the other side, standing upon the general floor, there is to be a 60-ton reverberatory, coal-fired furnaces, or else there will be two 40-ton furnaces, this point had not been settled when I was there, although the rest of the plant was nearly done.

The blast furnaces are about 1,000 feet away and the direct-metal railway runs into the converting works at one side of the vessels on

the general level. From this point the direct-metal ladle may be lifted to the vessel by a high-jib crane, as before described, and tipped into the vessel. Or, by means of another lift or crane, (not yet constructed) the ladle may be lifted to such a height that its contents may be tapped out into the large reverberatory furnace. In this furnace it is the intention to store and keep hot some 60 tons of iron from all the blast furnaces. The vessel charges will be tapped out as required into a ladle, raised by the high-jib crane, and poured into the vessel.

"Although this large furnace may be the best means of mixing metal, so as to get a uniform result, the complex manipulations due to the arrangement described, seem likely to take an unnecessary amount of time and labor. The metal is lifted four times before it is run into ingot molds—once to the big furnace, once to the vessel, once to the ladle crane and once by the ladle crane. And it is going to be a somewhat difficult matter to stop the tap of a furnace with 50 tons of fluid metal behind it. Of course the ferrostatic pressure may be made small by keeping the bath shallow, and the great surface thus exposed would be favorably to heating the metal."

In his conclusions Mr. Holley states:

"Fourth. But if the storage of a large quantity of iron in a reverberatory furnace or other receiver should prove successful,
410 then a few blast furnaces, making even an irregular product, and, if necessary, working in connection with cupolas, would largely economize the Bessemer manufacture."

"In fact, this mixing of irregular irons on a very large scale, thus avoiding the expensive niceties of ore selection, and the necessity of many furnaces, is the theoretical key to the situation. When the way to its successful adoption is demonstrated, the direct process will undoubtedly have great advantages, even over the present practice on the continent, which employs manganiferous ores. But until this large-scale mixing is developed, it should not appear that the use of our comparatively irregular blast-furnace metal, and more especially the use of part blast furnace and part cupola metal, can result in any substantial saving.

"But the mixing problem is not such a difficult one. A small amount of flame spread over a large surface of metal should certainly keep it hot for a long time, seeing that the metal will keep hot in a ladle exposed to the air for an hour or more. And should there be any trouble about stopping the tap-hole in a large storing furnace, it would not be a very difficult or expensive matter (considering the Pernot revolving hearth experience), to tip the whole hearth enough to pour a charge.

"So, that, while we congratulate ourselves that the direct-metal users have no advantages over us in the present state of the art, we may look forward to the development of the metal-storing problem with good hope, not only of more economical manufacture, but of more uniform product."

I think it would be difficult to express more clearly than Mr. Holley has done, the disadvantages of the direct-metal process as at that time carried out, and the methods to be taken to overcome

these difficulties. At any rate, it is evident that the mixing of metal from blast furnaces had at that time engaged the attention of metallurgists, and that efforts were being made to properly carry out this mixing. Certainly, any one skilled in the art would have been able, from Mr. Holley's descriptions, and discussion, to construct a practical "mixer" and to make it work.

411 It is evident that in the case of both forms of mixer described by Mr. Holley the intention was: First, to mix molten metal from several blast furnaces, or different casts from the same furnace, in order to secure uniformity in its constituent parts preparatory to further treatment; second, to introduce into a mixing receptacle successive portions of molten metal non-uniform in constituents; third, to remove portions only of the composite molten contents of the receptacle, without necessarily draining or emptying the same; fourth, to successively replenish the receptacle with fresh non-uniform additions. It therefore appears to me that the discussion by Mr. Holley of the above points discloses a practice which would embody the process shown in the Jones patent.

Q. 61. Mr. James Gayley, an expert witness called on behalf of complainants, in giving his testimony in answer to question 6, says, "That the metal can either be mixed by charging it into the cupola and remelting, thus securing an average of the varying grades, or else by pouring it into a metal mixer of large capacity, and withdrawing therefrom for use in the Bessemer converter instead of from the cupola." He then says: "The metal in the mixer remaining for a long time in a heated state, renders this feasible." From your experience in mixing metals in South Chicago, other places, how long is it necessary for metal to remain in the mixer to cause averaging thereof?

A. I do not consider that any special time is necessary in the mixer to produce the mixing. It is my opinion that the mixing will take place as soon as the pouring together of the portions of liquid metal has taken place. The varying heats of the molten metal additions might cause better or worse mixing during the act of pouring, but I do not consider that any benefit to the mixture would result from waiting any long time after pouring is complete.

Q. 62. Mr. Gayley, in his answer No. 6, refers to the practice of the Edgar Thomson works endeavoring to keep the mixer constantly full. Is this your practice at South Chicago, and did

412 you find it necessary to do so or derive any benefits from so doing?

A. The benefit of keeping the mixer full would chiefly reside in the fact that a large mass of metal remains hot longer than a small one, and at South Chicago the practice was, of course, to keep as much metal as possible in the mixer, but it was not considered essential to have the mixer full to any particular level.

Q. 63. Mr. Gayley says, in answer to cross question No. 67, "Capt. Jones is, as far as my knowledge goes, the first person to have attempted the mixing of molten metal from different furnaces for use in a Bessemer converter." Considering that he did this in

the year 1887, is he the first person who actually mixed molten metal from different furnaces, or molten blast metal from different furnaces for use in a Bessemer converter?

A. In the light of the practice I have cited at South Chicago, and that disclosed in the publications I have referred to, I would say that molten metal had been mixed for purposes of conversion by the Bessemer process a considerable time before Capt. Jones did so.

Q. 64. In answer to cross-question No. 101, Mr. Gayley says: "The principal part of the mixing of the metal is obtained by pouring the new charge into the old, but is further increased by the tilting of the vessel for discharging, and by the general law of the diffusion of metals, which always prevails in liquids of varying composition." Was the law of the diffusion of liquids known prior to 1887?

A. Yes.

Q. 65. What is the general shape of the mixer employed at the South Chicago works, which was designed or erected under your supervision?

A. It is a cylinder, wheeling on its axis to discharge metal, having a receiving spout at one end and a discharging spout on one side near the end, the wheeling of the cylinder bringing this
413 latter spout below the level of the metal in mixer, and causing pouring.

Q. 66. Is there any agitation of the metal in the mixer arising solely from the wheeling thereof to pour?

A. This agitation would be very slight, indeed.

Cross-examination by Mr. BAKEWELL:

X Q. 67. Are you familiar with the operation of the process of the patent in suit, as carried on at the Cambria iron works?

A. I have not seen the mixer at Cambria in operation.

X Q. 68. Nevertheless, do you not have a correct understanding of the manner in which that process is carried on at those works?

A. I understand that metal is mixed there by pouring into a vessel or mixer, but when I was last at Cambria the mixer had not been completed, and was not in use.

X Q. 69. As you understand the operation of the process referred to at the works of defendant's counsel, is that process not accurately described in the first and second claims of the patent in suit?

Witness is instructed by defendant's counsel that he is to testify as to things within his own knowledge, and that as to matters of fact regarding which he has no personal or direct knowledge, he is to state that fact.

A. I have already stated that I have no personal or direct knowledge as to the operation of the mixer at the Cambria iron works.

X Q. 70. Then as I understand you, you have seen the apparatus at the works of the defendant company, but that knowledge derived in that way is not sufficient to enable you to testify as to the process to be carried on thereby, is that so?

A. I can hardly be said to have seen the apparatus at the Cambria works, for the machinery, etc., had not been installed when I was last there. In fact, I can hardly say that I saw anything of the apparatus proposed to be used.

414 X Q. 71. Is it not a fact that the introduction of the mixing reservoir produced an important improvement in Bessemer direct process?

A. The introduction of the mixer certainly made some changes in the direct-process practice, and conduced especially to rapidity and regularity of operation.

X Q. 72. Is it not also a fact that after the introduction of the Jones mixing reservoir practice at the works of the complainant company, that process began to be used and has since been very generally adopted?

A. Some years elapsed after the installation of the mixer at the Edgar Thomson works, of the complainant, before another mixer was put up at any other works. I am not able to give exact dates, but my impression is what I have stated. I believe the mixer is now in use at four works besides those of complainant.

X Q. 73. In your opinion did not this delay in the introduction of the Jones mixing reservoir and process, at works other than those of the complainant company, result from a desire to ascertain first, the practicability or value of such process and apparatus?

A. Undoubtedly the manufacturers were waiting to see how the process would result and what difficulties arose in operating the mixer. Possibly, also, they were deterred from using it by the idea that it would be necessary to use the Jones apparatus.

X Q. 74. Was not the Jones mixing reservoir the first mixer of its kind ever practically used in the art, so far as you know or as appears in the art as far as you understand it?

A. I believe the Jones apparatus to have been the first complete apparatus, at least an apparatus worked out in such detail and so well designed in all its parts.

X Q. 75. When the reservoir was built at the South Chicago works, did they not know of the Jones mixing reservoir and process?

415 A. Yes; the mixer was well known to the people at South Chicago.

X Q. 76. When, if you recollect, did you first learn of the Jones mixing vessel or process?

A. I saw the mixer in operation at complainant's works soon after it was installed. I cannot remember the date, but certainly within a year after its beginning operation.

X Q. 77. In your answer to question 7 you say that it was sometimes the practice to partly fill the ladles of one blast furnace and complete the filling with iron from other blast furnaces. Was not this the highest development of the art as practiced up to the date of the introduction of the Jones mixing reservoir?

A. This method of mixing was certainly in use, and was as far as a method for mixing could be carried, without the use of special apparatus for that purpose.

X Q. 78. In tapping the blast furnace was it practicable to stop the flow of metal by plugging the tap-hole when a part only of the charge was withdrawn?

A. It was not practiced as a regular thing, but has been done in emergencies.

X Q. 79. The ferrostatic pressure in the blast furnace, under the circumstances referred to in the last question, would render it practically impossible to be practiced as a regular thing, would it not?

A. I do not see the impossibility of stopping the blast furnace under the circumstances you mention, and think that if arrangements were made as they are in the cupola furnace for facilitating the operation of stopping up, the thing might be done without danger or much difficulty.

X Q. 80. Why, then, was this not done as a regular thing?

A. Because it is and was desirable to maintain as regular as possible the operation of a blast furnace. The stopping up might involve more or less delay, which blast-furnace men always
416 object to. I think that the natural conservatism of the blast-furnace men may also have something to do with it.

X Q. 81. What is the capacity of the South Chicago mixer?

A. Each mixer has a capacity of about 150 tons.

X Q. 82. And what is the capacity of the converters used in connection with them?

A. The heats at South Chicago will average about 11 tons of ingots.

X Q. 83. In your answer to question 15, in speaking of some of the advantages of the use of the mixing reservoir, you say that one incidental advantage was that to a certain extent mixture of metal took place in the mixer, giving a better average of metal for conversion. Do you mean a better chemical average?

A. Yes; I meant a better chemical composition of the metal, so far as mixing may be said to have taken place.

X Q. 84. Notwithstanding the fact which you have stated in your answer to question 15, that in respect to the cost of transportation, it was more expensive to use the mixer than to carry the metal in ladles to the converter. Have you not found in your experience that there was still a large practical advantage obtained by the use of the mixer?

A. My answer to question 16 I thought made it clear that I was speaking of the metal delivered to the converter. I have never disputed that there is an incidental advantage in the use of the mixer, aside of its principal function of delivering accurately weighed charges to the converter. By the word mixer in this answer I wish to be understood as meaning any form of apparatus in which mixing can take place.

X Q. 85. When the mixing reservoir was introduced into use at the South Chicago works did you then discontinue the use of cupola furnaces altogether for remelting the metal for the converter?

A. No; we did not.

417 X Q. 86. I understand from your testimony that in the Bessemer practice the cupola metal is substantially uniform.

How is it that this practical uniformity is obtained from the cupola when it does not result from the use of the blast furnace? Is it not because the character of the resultant cupola metal is predetermined by a careful selection of cold pig with which the cupola is charged?

A. I am not aware that I have made the statement that cupola metal is uniform.

X Q. 87. I did not in my last question refer to absolute uniformity but to substantial uniformity. Is it not a fact that the resultant metal from the cupola is much more uniform than that resulting from the blast furnaces; and if so, is not this caused by the careful selection of the pig charge of the cupola furnaces?

A. If by resultant metal is meant the molten metal as it flows from the cupola, I do not think that it can be said to be uniform. The metal after flowing down the runner from the cupola and falling into the ladle below undoubtedly becomes mixed, so that the contents of any particular ladle may be said to be substantially uniform.

X Q. 88. In the exclusive use of cupola metal in Bessemer practice would you consider the degree of ununiformity in the charge of molten metal to the converter to make it important to employ the mixing reservoir?

A. No, I should say it was not necessary.

X Q. 89. Is it not a fact that by the direct process you obtain an advantage in that you are enabled to make Bessemer pig with a less percentage of silicon than when the metal is run into pigs and remelted?

A. Undoubtedly the direct process requires less silicon than the cupola-melting process; but I do not think as a matter of fact that a substantial lower silicon percentage in the pig iron has been made and is now made for the direct process.

418 X Q. 90. In your testimony-in-chief, you have stated the similarity which you find to exist between the Jones mixer and process and the Deighton, Witherow and Bessemer process respectively. And, as I understand it, you recognize there is some difference between the Jones mixer process and the others which I have named. Will you please state what these differences are, in your opinion?

A. I do not consider the differences between the Jones method and the others mentioned to be essential. All the processes mentioned mix molten metal and withdraw portions for use, and in my judgment there is a considerable likeness between all the methods mentioned.

X Q. 91. You do not wish me to understand, do you, that the Deighton, Witherow and Bessemer processes, as referred to in your answer to question 43 respectively, are the same as the Jones process, as described in the patent in suit?

A. I see no essential differences in the methods of the processes referred to, beyond what may be accounted for by varying kinds of apparatus and the conditions of the art at the times when the different methods were proposed.

X Q. 92. In your last answer please to state what you mean by the word "method" as you have used it?

A. I used the word method in preference to the word process, inasmuch as I do not think that any of the methods mentioned are entitled to the name "process."

X Q. 93. In your answer to question 44, in referring to the article in the Journal of the Iron and Steel Institute of 1878, you say that you find it stated that the Moss Bay Company attempted to modify the thing some time ago, and put up a heating furnace; but that, to his mind, it was a step in the wrong direction. State whether you agree with Mr. Snelus in this statement, that it was a step in the wrong direction, and if so, for what reason.

Objected to as incompetent and immaterial.

A. I hardly think I would attempt to say at this late day, whether I agree with Mr. Snelus in his remark made in
419 1878 or not. The remark as quoted in the article might mean many things. It is not stated for what purpose or for what sort of a furnace it was intended, and I hardly think I can express an opinion on this matter.

X Q. 94. In the use of the Deighton apparatus, as described in his patent referred to in your examination-in-chief, when used in connection with blast furnaces, would it not be desirable before filling the receptacle from the blast furnaces, to empty it sufficiently to receive the whole tapping of one of those furnaces, in order to avoid the inconvenient practice of plugging up the blast furnace before the metal is all discharged?

A. It would, of course, be desirable to make sufficient room in the receptacle for the metal which it was proposed to put in it.

X Q. 95. *Is* the patent to James P. Witherow, No. 327,425, which you have referred to, state for what purpose Witherow proposed to use his series of tap-holes one above the other?

A. I find it stated in the specification that the tapping hole referred to "may be arranged as to relative height, with reference to the capacity of the vessel, so that the opening of any particular hole will ensure the delivery of a predetermined quantity of metal. In this way the use of a weighing ladle or other means of determining the charge of the converter may be rendered unnecessary. If it is desired to tap off a slag it may be done by opening the proper tapping hole H." In the light of this description I should say the tapping hole might or might not be used either for letting out of the receiver a certain quantity of metal in the absence of a scale on which to weigh issuing metal, or they might be used to tap off slag which would float on the top of the metal.

X Q. 96. If a charge of molten pig metal is placed on the hearth of a reverbatory gas furnace, and kept there for a time, say
420 a couple of hours or more, what would probably be the result or the effect produced on the chemical composition of the metal?

A. This would depend upon the temperature at which this charge was maintained in the hearth, the presence or absence of a reducing

flame, the kind of bottom in the furnace, and whether all access of air was or was not prevented.

X Q. 97. Please answer the foregoing question under the supposition that I referred to the ordinary conditions under which such furnaces are used.

A. I understand you to refer, then, to an open-hearth furnace used for melting steel and charged with a bath of pig iron kept molten in that furnace for two hours. Under these conditions, and if the furnace is worked without special reference to exclusion of air, it is probable that some silicon would be oxidized, as is always the case when a large body of metal is maintained in a molten condition.

X Q. 98. Will you please state, Mr. Forsyth, for how long you had known Capt. Jones prior to his death, and what you knew about his experience and proficiency in the art of making Bessemer steel and kindred metal-urgical subjects?

A. My acquaintance with Captain Jones dates back to 1871; we were intimate friends from that time until his death in 1889. I considered him and still consider him one of the foremost metal-urgical and steel engineers of this country.

X Q. 99. Do you remember when it was Capt. Jones died?

A. Captain Jones died in September, 1889.

X Q. 100. And do you remember the manner of his death?

A. Captain Jones died from the result of burns received at one of the blast furnaces of the Carnegie Steel Company, which furnace he was engaged in attempting to bring back to its proper work-
421 ing condition. The furnace is understood to have been scaffolded and Captain Jones was working about the hearth of the furnace when an explosion took place. He was covered with molten metal and with several other men, was very severely burnt.

Redirect examination by Mr. DODGE:

R. D. Q. 101. Were you present at the time when the accident happened to Jones?

A. I was not.

R. D. Q. 102. Your information respecting the injury and cause of death was derived from others?

A. Entirely, I heard of the accident while in Chicago, and that it would probably prove fatal. I heard also on arriving at Pittsburg that the injuries would certainly prove fatal; and the matter was particularly distressing and noteworthy from the fact of which I was advised, that on the very day of his injury he had disposed of his patent for the mixer, to the Carnegie Steel Company.

R. D. Q. 103. In answer 71 you say that the introduction of a mixer made certain changes in the direct metal practice. Please say whether those results would have been obtained in your opinion by the use of the Deighton, Witherow or other apparatus in the manner described in the patents to which you have referred?

A. Any of these apparatuses would have made changes in the direct process; probably, considering the state of the art at the time

these different apparatuses were devised, it might be said that they were all on an equal footing. Undoubtedly the later forms of apparatus are more efficient and more easily handled than the earlier ones.

R. D. Q. 104. Do you mean more efficient as to the matter of mixing, or as to the ease with which they could be operated?

A. I mean with regard to the ease with which they can be operated.

R. D. Q. 105. You have referred to four plants other than that of complainant, using mixers. Do either of these plants use
422 the form of apparatus shown in the drawing of the Jones patent?

A. I believe they do not.

R. D. Q. 106. Is it or not, a fact, that since 1873 there has been a steady growth in the size and output of the blast furnaces in general use, and in the capacity or consumption of metal by the converters?

A. There has been a very great increase in both size and product of blast furnaces since that time, and also in the capacity of the converting works. The size of the converters has considerably increased. In 1872 I think there was no converter in this country of a greater capacity than 6 tons.

At present there are many converters over ten tons and some, I believe, of 18 tons.

R. D. Q. 107. In question 73 certain reasons are suggested why manufacturers delayed the introduction of mixers. May there not have been other causes such as the inconvenient arrangement of their plants, limited capacity of the blast furnaces, affecting the matter?

Objected to.

A. These matters undoubtedly had their influence and a very decided one.

R. D. Q. 108. In what sense do you refer to the Jones apparatus as "complete" in answer 74?

A. I mean by this complete in the way that an engineer should use the term, well designed, efficient, good apparatus.

R. D. Q. 109. Please say whether or not the Deighton and Witherow apparatus was a special apparatus within the meaning of your answer 77?

A. Either the Deighton or the Witherow apparatus, in the hands of a competent and skilled metal-urgical engineer, would I think have accomplished the mixing of metals in a satisfactory manner. I should consider them as coming under the head of this special apparatus in my answer.

423 R. D. Q. 110. You have been questioned as to the tapping of blast furnaces. Was it or not a common practice previous to 1888, to tap a blast furnace into a trough or runner and to divert the metal from this trough into different ladles to avoid the necessity of stopping the tapping hole?

Objected to as obnoxiously suggestive, if not absolutely leading.

A. It was certainly common practice to tap blast furnace in the manner described into a runner leading to a ladle. It certainly was not the rule to stop up furnaces at that time, so long as metal was flowing out. The ladles were there to take whatever metal presented itself, and usually did so.

ROBERT FORSYTH.

424 *Testimony of William J. Taylor.*

WILLIAM J. TAYLOR, a witness called on the part of defendants, being first duly sworn, deposes as follows:

By Mr. KAY:

Q. 1. State your name, age, residence and occupation.

A. William J. Taylor; residence, Bound Brook, Somerset county, N. J.; age, 60; occupation, manufacturer of iron.

Q. 2. With what company are you connected in the manufacture of iron, and what kind of iron do they produce?

A. Taylor Iron & Steel Company, of High Bridge, N. J. We make car wheels, axles, etc.

Q. 3. In the manufacture of car wheels, does your company employ one or more cupola furnaces?

A. Yes, we have three in the wheel foundry.

Q. 4 Into what do you tap the metal from the cupola or cupolas in the regular operation of the foundry?

A. Tap it into a reservoir.

Q. 5. About what is the capacity of that reservoir?

A. We used to use it with the reservoir about the full capacity of the cupola, that is to say, a cupola that would hold 20 tons—we had a reservoir large enough to hold 20 tons.

Q. 6. What was done with the metal so tapped from the cupola into the reservoir?

A. After the metal was all melted in cupola, run into the reservoir and stirred up to mix it thoroughly, we poured it into car wheels.

Q. 7. When did you commence the practice which you have described in these works?

A. About the year '67 or '68.

Q. 8. Was that the practice which you always followed, or did you change that practice, running all the metal from the cupola into the ladle at one time?

425 A. When we first built the foundry in '66 we had a smaller reservoir that would not hold all the iron that the cupola would melt; when we enlarged, which I think was in '68, we put in a reservoir to hold the whole melt of the cupola, which was 20 tons.

Q. 9. When you had this smaller reservoir, what was your practice in casting car wheels?

A. It was just the same, only we poured some car wheels before all the metal was run into the reservoir.

Q. 10. In pouring some car wheels, did you entirely drain the reservoir, or did you leave some metal therein?

A. We never drained the reservoir, we only poured it when the reservoir would get full and the cupola wasn't empty—we would have to dump some wheels in order to take some iron out of the reservoir to run more iron from the cupola.

Q. 11. Would you then run the iron from the cupola into the metal remaining in the reservoir?

A. Yes, and stir it with a bar so as to mix it thoroughly.

Q. 12. For what purpose did you follow the practice of stirring the metal with a bar, in both the use of the large and small reservoir which you have described?

A. For the purpose of getting a thorough mixture, as thorough as possible.

Q. 13. Why was it necessary to get such a thorough mixture as you state?

A. Because you couldn't get it into the cupola—you simply put it in a reservoir to help it and make it more uniform and run it in and mix it before pouring the wheel.

Q. 14. About what weight of metal would you draw from the reservoir at one time for casting into car wheels, I mean the old reservoir?

A. We used to take one wheel of the smaller size, weighing 500 or 600 pounds, and the large one, we poured two wheels, which is our practice now.

426 Cross-examination by Mr. BAKEWELL:

X Q. 15. You say that before 1867 you used a smaller reservoir, too small to hold the entire tapping from the cupola?

A. I think it was; quite certain our first reservoir and our first cupola that we built, in '66 or '67, was that the reservoir was too small to hold the entire melt of the cupola, and we changed that when we built the new cupola, so that the last reservoir and cupola that we built in 1868 were built in harmony, that is, the reservoir would hold the full melt; we did not pour in wheels until we run all the metal out and dumped the cupola.

X Q. 16. And then your practice was to use up the melt in car wheels and when the reservoir was empty you would fill it up again?

A. No, that was the end of it—that was the day's work.

X Q. 17. You mean that one melt a day, that you would pour this into the reservoir, and when this reservoir was empty the day's work was done?

A. Only one melt in the cupola per day.

X Q. 18. Now prior to '67, did you make more than one melt in the cupola per day?

A. No, nor do we today. That is the regular foundry practice. We have to pour now before we finish the melt. I think the reservoir would hardly hold the melt now in the cupolas.

X Q. 19. But up to recently you would tap the melt into the reservoir and not begin casting the wheels until the melt was all drawn from the cupolas?

A. Until the melt was all drawn from the cupola. We did that for years.

X Q. 20. Why did you change so as to get a reservoir large enough to hold all the metal taken from the cupola?

A. Well, because Mr. Stanley, who was an old and very competent car-wheel maker 30 years ago considered that that was necessary to get a thorough mixture of iron.

X Q. 21. By the use of the large reservoir?

427 A. By the use of a large reservoir—and then he wanted to stir it, after it got two-thirds or half full he had the iron stirred so as to get it thoroughly mixed.

X Q. 22. What was the capacity of the reservoir that you used prior to '68?

A. Prior to 1868, about 10 tons.

X Q. 23. And your cupola capacity at that time?

A. I can't tell exactly—all I know is that in the beginning we did not have reservoir capacity enough to run the whole melt and when we rebuilt Mr. Stanley considered it of so much importance, that we put in a larger reservoir.

X Q. 24. How long did you use the smaller reservoir?

A. We used it more or less until it was worn out. We used the smaller plant where we couldn't treat all the metal; we did not do as good work, but we couldn't help it.

X Q. 25. What was the cupola capacity used with the smaller reservoir?

A. I gave you the capacity of that reservoir, about 10 tons. Now if the capacity of the cupola is half we ought to be able to run that reservoir full, but I know that we didn't. Think the cupola was about half the capacity and the reservoir was smaller than 10 tons.

X Q. 26. How much smaller?

A. I should suppose 7 or 8 tons.

X Q. 27. Then after drawing, that would leave about one ton short, or two tons short of the capacity of the cupola?

A. One to three tons, because we would have begun to pour before we could take all the iron from the cupola.

X Q. 28. Then you would only have to draw from 1 to 3 tons out from the reservoir and then you would pour all the rest from the cupola before repeating cast?

A. Yes; tap the rest from the cupola.

X Q. 29. When you say from 1 to 3 tons you say that you recollection is not now clear enough to say exactly what the difference was?

428 A. The only distinct recollection I have is that the first foundry that we built, and the first reservoir and cupola we could not run the whole melt into the reservoir and when we rebuilt Mr. Stanley advised that it was very important that the reser-

voir should be large enough to hold the whole of the melt and that it should be thoroughly mixed with bars; that is how we built.

X Q. 30. Now in charging your cupola furnaces what care did you use in selecting the pig metal that you put into them?

A. All that I can tell you is that we used all the care possible.

X Q. 31. What kind of pig metal did you select?

A. We selected the pig iron that gives us sufficient chill with the greatest strength.

X Q. 32. This reservoir that you speak of was a ladle?

A. No; it was a reservoir; we poured from the reservoir to the ladles to carry the iron.

X Q. 33. You mean poured from the reservoir to the casting ladles?

A. Yes.

X Q. 34. Tapped directly from the cupola into the reservoir?

A. Yes.

Redirect examination by Mr. KAY:

R. D. Q. 35. In preparing the metal for the cupola did you use only pig metal or did you use other metal besides?

A. We used other metal in addition to pig—old car wheels, scrap and pig iron.

Recross-examination by Mr. BAKEWELL:

R. X Q. 36. But in using these different wheels you selected them and apportioned them so that the total is right?

A. Yes.

429 R. X Q. 37. Do you mean sometimes part of the charge melts before the rest?

A. Yes.

R. X Q. 38. Therefore you run it all into the reservoir to get the old car wheels mixed with the pig, so that you would be sure that the old car wheels eventually got down into the pig and the pig iron into scrap which you had previously carefully selected and apportioned?

A. ——.

Signature waived.

Depositions of witnesses and other evidence on the part of defendants in the above causes, taken at the office of Kay & Totten, No. 96 Diamond St., Pittsburgh, Pa., before Robert C. Totten, notary public and examiner, by agreement of counsel, commencing Monday, Dec. 28th, 1896, and continuing by adjournment, said depositions being taken at the times and place agreed upon by counsel for the respective parties.

Present: William Bakewell, Esq., and J. K. Bakewell, Esq., for complainant; and P. T. Dodge, Esq., and James I. Kay, Esq., for defendants.

430 *Testimony of Robert W. Hunt.*

Robert W. Hunt, a witness called on behalf of the defendants, being first duly sworn, deposes as follows in answer to questions put to him by Mr. Kay:

Q. 1. State your name, age, residence and occupation.

A. My name is Robert W. Hunt, age 58 years, residence Chicago, occupation metallurgical and consulting engineer.

Q. 2. Have you had any experience in connection with the manufacture of Bessemer steel? If so, at what time did that experience commence?

A. My experience commenced in 1865 at the experimental Bessemer works, Wyandotte, Michigan. Previous to that time I had been analytical chemist for the Cambria Iron Co., Johnstown, Pa., they sending me to Wyandotte in their interest. I had also been superintendent of the Elmira rolling mill, at Elmira, New York. My experience commenced in 1857 at the Pottsville Rolling Mill Company, Pottsville, Pa., and from that time to the present has been continuous except during the war.

Q. 3. Will you please state briefly the different works with which you have been connected, either having charge or otherwise, for the manufacture of Bessemer steel from 1865 to the present date?

A. I assumed charge of the Wyandotte works in July, 1865, so remaining until the first of May, 1866. I then returned to the Cambria—had charge of their steel business, they rolling steel produced by the Pennsylvania Steel Company into finished product. Later I assisted the chief engineer of the Cambria Company, George Fritz, in designing and constructing the Bessemer works at Johnstown for that company at Johnstown. Upon their completion in July, 1871, I assumed charge of them and so remained until the first of September, 1873. I then became superintendent of
431 the Bessemer works of John A. Griswold & Co., Troy, N. Y. I remained with that company and its successors, the Albany, Rens-el/aer Iron & Steel Company, and the Troy Steel and Iron Company becoming the general superintendent of the works until the first of April, 1888. Since then I have been engaged as the head of the firm of Robert W. Hunt & Co, whose principal business is the inspection of metal products for the principal railroads of the United States, which has kept me in constant intercourse with the

various steel and iron works of the country, particularly Bessemer works producing steel rails.

Q. 4. Have you been connected with any technical societies in this or European countries, and have you held any position in them, and if so, what?

A. I have been and am a member of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the Western Society of Engineers. I have been president of the American Institute Mining Engineers, the American Society of Mechanical Engineers and the Western Society of Engineers.

Q. 5. Are you the author of the article entitled "The history of the Bessemer manufacture in America," by Robert W. Hunt, which is contained in the publication entitled "Transactions of the American Institute of Mining Engineers," volume 5, May, 1876, to February, 1877?

A. I am.

Q. 6. Can you state the circumstances of preparing that article and reading that article?

A. I prepared it and read it at the meeting of the American Institute of Mining Engineers at the meeting held in Philadelphia in the year of our national centennial and as being appropriate to that occasion.

Q. 7. To save a long line of questions, I ask simply whether the facts set forth in this article are true, or were believed to be true when you prepared it?

432 A. I certainly believed them to be true, and took great pains in preparing the article and verifying my figures and statements by consultations with the proper parties and records. Many of the facts given were personally known to me. Hence, I was very positive as to their accuracy.

Q. 8. In reading the paper referred to, I see that you were intimately acquainted with Mr. A. L. Holley and with Captain W. R. Jones, the patentee of the patent in suit. Will you please state how intimate you were with these gentlemen, and also if you know how intimate they were with each other?

A. They were probably my two most intimate friends. My intimacy with Mr. Holley began in 1867 and continued until his death, and it would be hard for two men to be closer to each other than he and I. Captain Jones was associated with me in the service of the Cambria Iron Company from 1866 until the summer of '73, when he resigned his position as master mechanic and assistant general superintendent to enter the employment of the Edgar Thomson Steel Company, he having obtained that position through Mr. Holley's influence. During the early years of the Bessemer business in this country there was a very remarkable intimacy existing between the persons in charge of the several works, and as Mr. Holley was connected with practically all of them, either as consulting engineer or in other official capacities, it resulted in his coming constantly in contact with the several managers; and, in fact, many of them had been induced to enter the business by him, and had

taken their first lessons in works under his charge, and it was a new business, surrounded by many difficulties, and such friendship existing, there was a constant interchange of ideas and experience. Many of these communications were through the mediumship of Mr. Holley in his visits to the various works. Hence, it made what might be called a brotherhood, of which Holley was recog-
433 nized as the head, and in this association there were none closer or more constantly in contact than Holley and Jones.

Q. 9. How was the metal prepared for conversion in the works of the Cambria Iron Company when you had charge of the Bessemer plant there?

A. It was all what is technically known as cupola metal, that is, the mixture of the various grades of pig *were* charged and melted in cupola furnaces and accumulated in the intermediate or mixing ladle, and from that poured into the converter, and, of course, as this ladle stood on scales, it was weighed and definite amounts were obtained.

Q. 10. As you operated at that works would there be any metal remaining in the ladle after the weight for the converter charge was withdrawn, and what was your practice as to refilling the ladle?

A. There was no absolute rule. Whether or not metal was left after pouring the charge depended upon the relative speed which the cupolas were melting and the metal being conmverted in the converters. If the blowing was close up to the melting the metal would be poured as soon as sufficient amount for a heat was accumulated. If on the contrary the melting was ahead or faster than the conversion there would be frequently a large proportion of another heat retained in the ladle after pouring and into which more metal would be tapped from the cupolas. You will appreciate that in cupola practice only a given length of time can intervene between the tapping, as the melted metal accumulating in the hearth or bottom of the cupola will get as high as the tweers and if not drawn off would run into them and chill and close them up, the only other alternative being the shutting off of the blast, which is bad practice and liable to interrupt the satisfactory working of the cupola furnace.

Q. 11. Where metal was left in the ladle after withdrawing the charge, was there any recognition at the time that you
434 worked at the Cambria of the fact that there was a mixing of the metal subsequently tapped into the ladle with that which remained therein and of any advantages arising from it?

A. Very decidedly so. It was recognized as one of the great features of the intermediate ladle, that it made the work so much more uniform in results from such mixture or evening up of the various grades of pig iron used.

Q. 13. How uniform was the metal tapped from the several cupolas into the ladle?

A. I can't speak from any actual determination. I mean by that chemical determinations, but as the charges in cupolas varied in physical character if not in chemical, of necessity the metal did not

come from them of a uniform character. I mean by this that in addition to the pig iron which was charged in them, steel scrap was also melted, which would vary very greatly as to its size. It will be easily appreciated by any one familiar with the art that if the steel scrap happened to be a butt or short end of an ingot or bloom it would not melt as fast as other scrap of smaller section or as fast as the pieces of pig iron. Again the pigs themselves varied in size, and the smaller the section the quicker they would melt. Moreover, several cupolas, from two to three in those days, as a rule two, were being tapped into the one ladle and from various causes one cupola might be melting hotter and faster than the other one hence the iron, both in physical condition as to heat and chemical condition as to mixture, would come into the ladle varying in character, but in it be made more uniform.

Q. 14. About what were the comparitive sizes of the intermediate ladle and of the charges for the converter at the Cambria works?

A. The ladle was large enough to hold about one and a half heats or charges.

Q. 15. When you had charge of the works at Troy what was your practice there in preparing metal for the converter?

435 A. Practically the same as the Cambria, although the works differed in capacity. Moreover, I rebuilt the Troy works several times, increasing the size of the converters, and hence increased the size of the intermediate ladles to a proportionate extent.

Q. 16. How many cupolas did you have?

A. At Troy we had four, and the regular practice was to have three of them melting and tapping into the ladle at the same time, the relative capacity of the converters and ladles remaining about the same, although in the last alteration I increased the size of the ladles to hold nearly two charges.

Q. 17. Were you, prior to 1887, familiar with what is known as the direct-metal process?

A. I was. The earliest steel that I made at Wyandotte was metal direct from the blast furnace, and though after that had not personal experience I had seen it in operation during visits to both the South works of the then North Chicago Rolling Mill Co., and the Edgar Thomson works. I was also familiar with the experience of the Bethlehem Co. and also through technical literature.

Q. 18. Have you examined the letters patent to William R. Jones, involved in this suit, and if so, do you understand the invention set forth therein? I ask you to answer this question as a skilled metallurgist and engineer, and not as a patent expert.

A. I have, and do.

Q. 19. Considering the patent in the light of a practical steel manufacturer and mechanical engineer, what do you understand the supposed invention set forth in the patent to be?

A. The equalization of the varying chemical qualities of molten metal by mixing it in a suitable receptacle.

Q. 20. Do you understand the invention to be limited to such mixing of metal direct from the blast furnaces?

436 A. While the first claim leads one to infer metal from the blast furnace was principally considered, the title of the patent, as well as the second claim, would seem not to so limit it, thus making it include any molten metal no matter how obtained.

Q. 21. Has the term "molten metal" any distinctive meaning in the art of making Bessemer steel?

A. It means any metal that is in a liquid condition through the application of heat.

Q. 22. In the making of steel what term is generally used for the metal which is drawn from the blast furnaces and without casting into pigs is introduced in the molten state into the converter?

A. Direct metal. The process is known as the direct process.

Q. 23. By what terms is metal known which has been cast into pigs and is subsequently melted in cupola for Bessemerizing?

A. Cupola metal, which is of course molten metal.

Q. 24. Is there any essential difference between the molten metal drawn from a blast furnace and the molten metal remelted in a cupola?

A. They are both molten cast iron, containing certain alloys or impurities such as carbon, silicon, phosphorus, sulphur, etc.

Q. 25. Is there chemical difference between these metals?

A. Not of necessity, no.

Q. 26. In the carrying out of this supposed method described in the Jones patent, is it necessary to take the metal from more than one furnace, as you understand it?

A. No.

Q. 27. The practice admitted as you understand it described in the patent, where can the metal be obtained which is to be mixed together.

437 A. From one or more smelting furnaces of any character, or at different times from the same furnace, either different casts or parts of the same cast; thus with the blast furnace in consideration the metal may be taken from the first of the cast, then again intermediate or last of the cast, or from parts of the cast from two different blast furnaces.

Q. 29. Is it or not a fact that metal in one cast will differ in proportion of alloy or impurities at different parts of that cast?

A. It will, that is well recognized as a metallurgical fact.

Q. 30. Do you understand that the invention is to be practiced only in a large receptacle such as shown in the drawings of this patent?

A. Captain Jones certainly did not limit himself, as he expressly states that it may be practiced in a charging ladle which in the art would be accepted as meaning an ordinary intermediate Bessemer ladle, containing, as I have already stated, from one and a half to two converter charges of metal. In other words, he seems to base his claim on the fact of mixing metals varying chemically and otherwise together no matter in what bulk.

Q. 31. Do you understand from the patent that there is any necessity of actual agitation of the metal after it is introduced into the mixing vessel or receptacle?

A. Not other than the agitation by pouring of metal into the ladle.

Q. 32. Referring to the first claim of this patent, and I will ask you to consider it as a practical steel-maker; I believe you said that it referred to metal taken directly from the smelting furnaces. What is the essential point of that claim as you would read it?

A. Certainly, the equalization of the chemical composition of the metal by thoroughly mixing the various charges.

Q. 33. Is the last step of that claim "Subsequently refining the mixed and equalized charge," a new one?

438 A. Surely not. It is the regular Bessemer process, or, other refining processes.

Q. 34. When, as you stated, you knew of the practice at South Chicago with direct metal prior to 1887, did you then know of the mixing of charges from two blast furnaces to make up the single converter charge?

A. I did.

Q. 35. In this connection I also call your attention to the article in the Journal of the Iron and Steel Institute of 1871, pages 413 and 414, giving a description of the Terre Noire practice, and would ask you as to what bearing such South Chicago practice and such Terre Noire practice has upon the first claim of the Jones patent?

A. They are the same, as I find it stated that at Terre Noire they filled a ladle half full at one furnace, and then ran it to another one where the filling was completed. They thus obtained mixture of the metals and obtained great regularity therefrom in the rest of the work, or, of course, in the subsequent refining thereby they obtained the same results as set forth in the first claim of the Jones patent. In this mixture of metals from different furnaces in the ladle they did absolutely the same thing, and accomplished the same results as set forth in the first claim of the Jones patent.

Q. 36. Now, please look at the second claim of the patent and state as a practical metallurgist whether, as you understand it, it is limited to the use of blast-metal furnace?

A. No, sir.

Q. 37. What is the other step which makes this claim different from the first claim in the patent?

A. I can only say a difference in that the second claim covers manipulation of the apparatus as he specifies, that the receptacle shall not be entirely emptied or drained, and other metal shall be added to that which is allowed to remain in it after pouring off a certain quantity.

439 Q. 38. I call your attention to the Deighton English patent No. 3672, of 1873. Do you understand the invention set forth therein?

A. I do.

Q. 39. Please state what bearing this patent has upon the method described in the Jones patent in suit.

A. It is a description of absolutely the same method. By the use of one intermediate receptacle sufficiently large to receive more than the required charge for the converter and tapping into it

molten metal from two or more smelting furnaces. This is clearly shown in the sixth statement of the Deighton patent, which is as follows:

"A system or mode of arranging and working the Bessemer converters with the receiver or receptacle *m*, for mixing the molten metal from two or more smelting furnaces to get a more uniform quality of metal substantially as hereinbefore described and illustrated by the drawings."

Q. 40. Have you been accustomed to calculating the capacity of vessels for holding metal, and if so, will you state as to about how many converter charges the vessel *m*, shown in the Deighton patent will hold.

A. I am, and the converters, estimating them to have the usual thickness of lining, would seem to be intended for five-ton converters, or of sufficient size to handle a five-ton charge. On this basis the receiving receptacle is sufficient to hold about 140 tons molten metal. In estimating the capacity of the receiver *m*, I allow the same thickness of lining above the base of the spout as shown in this drawing as given for the sides.

Q. 41. Will you please state whether you understand that this mixing receptacle *m* is to be entirely drained of metal when the charge is tapped from it from what the patent shows in this regard?

A. In the first place, the size of the receptacle *m*, being so much greater than the capacity of the converters, shows that such
440 was not the intention, and again, in the patent it is stated "by placing the vessel *m* on a weighing machine it can be readily ascertained whether the exact quantity required has been tapped from it into the converter." Hence it was evident that Deighton intended and expected to leave molten metal in the receptacle after having drawn converter charge from it to which other metal would be subsequently added from the smelting furnaces.

Q. 42. I notice that this Deighton patent shows runners extending from the blast furnaces to this mixing receptacle. Would there be any practical difference so far as the mixing operation is concerned whether the metal was carried to the receptacle by runners or by ladles?

A. No, the mixing operation would go on just the same, but it would not be as neat and economical a plan as tapping direct into a ladle, owing to the probability of a certain amount of metal chilling in the runners and thus making scrap.

Q. 43. Was your knowledge of the use of runners or ladles prior to 1873 sufficient for you to state as to whether they were considered equivalent means of conducting the metal from one place to another? What was your knowledge in this regard?

A. Yes, they both were used, the selection being determined by the distance to which the metal had to be conducted.

Q. 44. What was the usual capacity of a blast furnace in resultant pig metal about the year 1873?

A. Of course, then as now, blast furnaces varied in size and ores

which they used, and, hence, in the capacity; but I should say that from 50 to 60 tons a day was regarded as about the maximum production.

Q. 45. How often would they tap blast furnaces in the normal working?

A. A very usual practice was three times in 24 hours, but in some works twice.

441 Q. 46. I call your attention to the Journal of the Iron and Steel Institute for the year 1874, pages 348 to 367 inclusive, the article being entitled "American rolling mills," by Mr. Alexander L. Holley, and would ask you to state briefly what bearing this article has upon the method of the Jones patent in suit?

A. I find that Mr. E. Windsor Richards stated that the practice at Terre Noire was as I have already commented upon, and that he had seen it in operation himself. In the same discussion, Mr. Snelus stated

"That there was no insuperable difficulty in running the iron direct from the blast furnace into the converter,"

And also went on to say that

"By running it into a separate vessel as they did in America, they could then deal with it as they liked. The plan in all the works in America was to melt in a cupola continuously, and then to run the iron into a ladle which was balanced and held from 10 to 12 tons. From that the six-ton charge was run direct into the converter. They wanted an intermediate vessel between the blast furnace and the converter."

The intermediate ladle to which Mr. Snelus referred was the cupola ladle designed by Mr. Holley, and which I have already described. He clearly and definitely pointed out that they wanted to make the direct-metal method more satisfactory, an intermediate vessel was required between the blast furnace and the converter, and as he refers to the fact that the cupola ladle would hold twice the contents of a Bessemer charge, he evidently considered that the receptacle for the blast-furnace metal should also be much larger than the amount required for the converter charges, which, of course, would mean that the metal should be left in it as these charges were withdrawn, and to which other metal would be added in the regular course of manufacture. It will be remembered that

442 I have already stated that this was the constant American cupola practice. This, of course, would be the same procedure as covered by the claims of the Jones patent.

Q. 47. I call your attention to the article in the Journal of the Iron and Steel Institute for 1876, pages 12 to 42, being a discussion of the use of molten iron direct from blast furnace for Bessemer purposes, and would ask you what bearing this has upon the patent in suit?

A. I find that this is a long discussion on the use of molten iron direct from the blast furnace for Bessemer purposes and that it was opened by Mr. Smith describing his success in conveying molten metal direct from blast furnace to Bessemer converter, and the president of the institute in opening it called attention to the fact

that it was then lately adopted in England although it was in general use on the continent. In Mr. Snelus' remarks he stated that they had been working direct metal for some time and that they were taking the metal from three blast furnaces. He stated also that he did not think it was advisable to take the iron from one furnace, but they might get an average mixture by taking it from two and they found no difficulty in taking three tons from one furnace, stopping the furnace up again and then going to another. Mr. Bessemer took part in the discussion and stated:

"The earliest idea he himself had ever entertained of the converting process was by the employment of molten metal direct from the blast furnaces, and it was only because he had not access to blast furnaces in his first experiments that these experiments were made with remelted pig iron."

And he further stated:

"He had himself proposed the tapping of three furnaces into one ladle or receiver, and when he advised some of his friends, in a company with which he was connected in the neighborhood of Barrow, to come into steel-making they arranged their works some two years ago so that the pig iron could be tapped into a ladle or rather into a spherical vessel with an almost close top to it, that would hold 20 tons. It was proposed to make at
443 least three seven-ton tappings into that vessel and to move it on wheels into the converting house, using a pair of converting vessels, one after the other until the four charges of five tons each were worked off; having the second ladle or vessel on its journey to supply so as to keep on working continuously."

In this discussion the methods of the Jones patent are clearly outlined. As the speakers emphasize the advantage of mixing the metal from several smelting furnaces in a ladle or receptacle of proper size, and, in fact, Mr. Bessemer goes so far as to point out his appreciation of the advantage of at least partially covering the vessel so as to retain the heat.

Q. 18. I call your attention to the article in "Engineering," March 9th, 1877, volume 23, pages 183 and 184, entitled "American iron and steel works," by A. L. Holley and Lenox Smith, relating to the Vulcan plant at St. Louis. Please state what bearing this article has upon the Jones method.

A. It is in the article stated that while no American works have as yet used metal direct from the blast furnace, the Vulcan plant was arranged anticipating such method and in case the metal for conversion did not come directly from the blast furnace the location of the furnaces for melting the spiegel and of the vessels were such as would not interfere with the convenient handling of blast-furnace metal. In fact, the arrangement would enable the convenient use of metal in part from the blast furnace and in part from the cupolas, bus it was the intention to use chiefly direct blast-furnace metal. But they also anticipated using some cupola metal to mix and temper the iron, which could in this way be done quicker than if they depended upon change of character of the metal from the blast furnaces. Accompanying this there is a drawing, by which I

see that the arrangement provides for tapping from three cupolas into regular cupola ladles or into the ladle coming from the blast furnace and then from either or both, poured into the con-
444 verters. This, of course, bears upon the patent so far as it recognizes this mixing or equalizing of metal and the use of an intermediate receptacle.

Q. 49. I call your attention to the Journal of the Iron and Steel Institute for 1878, pages 121 to 137, being a discussion which appears on page 144 of the same journal. Please state the bearing of this publication upon the method of the Jones patent in the suit.

A. I find that it is a report of a discussion on a paper read by Mr. Holland, and Mr. Snelus stated that:—

"He had been in correspondence with Mr. Holley who had informed him that at the Bethlehem works Mr. Fritz was doing half their work direct from the blast furnace, and had for some time had under consideration the idea of a receiving ladle, so as to receive the metal from the blast furnace, and hold it in readiness there for the converters. One great drawback to the direct process was, that you could not always get your metal at the exact time you wanted it. He believed it would be found that the great advantage the Bessemer works in America has was the intermediate receiving ladle which was designed by Mr. Holley, and which was universally used there, although it was never used in England. The Moss Bay Company attempted to modify the thing some time ago, and put up a heating furnace, but that, to his mind, was a step in the wrong direction. Anyhow, the thing had failed and no one in England as far as he knew, was using any intermediate receiver between the blast furnace and the converters. He thought himself that the receiver was of considerable importance, both for saving time and facilitating the admixture of iron; and he was confirmed in that view by the idea of Mr. Fritz of Bethlehem, who was about putting up a thirty-ton ladle, according to Mr. Holley, to receive the metal from the blast furnace, and hold it in readiness, so that at a moment's notice you could take your iron into the converter and also obtain a better mixture."

This clearly disclosed the method proposed in the Jones patent,
as it pointed out the advantages of an intermediate recep-
445 tacle other than a heating furnace and that it should be of sufficient size to hold much more than the converter charge, also clearly pointing to the retention of molten metal in the receiver to which other metal from the smelting furnace would be added, and also of its being of sufficient size to at all times have the metal ready for the converter, and it will be noticed that Mr. Snelus emphasizes the fact of the universal use by the American Bessemer works of the receiving ladle invented by Mr. Holley, and expresses his firm belief that the great advantage possessed by such works came largely from the use of such apparatus, thus emphasizing the accepted recognition of the advantage of an intermediate ladle of sufficient size to hold more metal than enough for a single converter charge, or, in other words, providing a reserve storage of metal.

Q. 51. About how many conversions per day were made in one

converter in the ordinary operation of a Bessemer plant in the neighborhood of '72 or '75?

A. Assuming that you mean a day of twelve hours I should say about 10 conversions per vessel or converter. You will appreciate that the usual Bessemer plant had two converters, the practice being to use one until its bottom or lining required repairs, and then the process was continued with the other converter, and so on. Such being the case, the total output of steel from such a plant per day of twelve hours was about 10 conversions.

Q. 52. Referring to the Deighton English patent about which you have testified above and to the fact that the reservoir *m* would hold a body of metal of several feet in depth, please state the practicability of tapping such a vessel so as to make up the necessary charges for the converter and closing or bottling up the tapping hole when the charge was withdrawn.

A. I am confident that it could have been done if care was exercised in regard to the size of the tapping hole used. It must be remembered that the state of the art at the time of the patent
446 under consideration was very different from what it is today, and the whole process was conducted very much slower, hence the amount of time which could be taken in transferring the charged metal from the receiver to the converter was very different from what it would be today. Therefore, it would have been practicable to have used a sized hole which could have been readily stopped against the pressure of metal remaining in the receiver.

Q. 53. Please state whether or not if difficulty had not been met in 1873 with the tapping of such a reservoir and the stopping in against the head of metal contained therein, means for overcoming such a difficulty were known to the skilled Bessemer worker.

A. I think in view of the difficulties which were overcome by the workers of that day this very much slighter one would not have stood in their way, and, as the inconveniences encountered in the use of a fixed Bessemer converter were overcome by making a suspended or turning one, it would seem natural to suppose that that means if no other would have been applied in this case. And it must be remembered that the Holley intermediate ladle was suspended on trunnions and poured the metal from its outer edge by tipping it. In this connection I would say that at that time it was the cupola practice to have more than one tapping hole, one being above the other. This same system, of course, could have been applied to the Deighton receiver.

Q. 54. You have said that you were intimately acquainted with Mr. A. L. Holley, and I believe also that he was the consulting engineer at the Troy iron works during the time that you had charge there and until his death. This is correct, is it not?

A. It is.

Q. 55. Had you any knowledge of Mr. Holley's reports which were made by him of examinations or inspections of Bessemer works?

447 A. Yes, I had. In fact, his printed or written reports came to me in my official capacity, and, of course, during his frequent visits we had conversations in relation to what he had observed, and, based on that, what he would recommend.

Q. 56. I call your attention to a printed article by Mr. A. L. Holley, entitled "The direct use of blast-furnace metal in the Bessemer process," being also marked No. 2, second series, and being also marked copyright, 1877, A. L. Holley. Have you any knowledge of this article?

A. A printed copy of it came to me as part of his regular reports at the time of its being issued.

Q. 57. Do you know whether Mr. Holley had any special relation with the steel manufacturers of the United States at the time that this article was issued, and what that relation was?

A. He was employed as consulting engineer by practically all the Bessemer manufacturers of the United States, and part of his duties, in fact at that time it was regarded as the most important part, was to keep them informed as to the foreign practice in the Bessemer business. It was his habit to make a trip abroad at least once a year for the purpose of obtaining data for these reports and which he, after proper preparation, distributed to his clients in the Bessemer manufacture.

Q. 58. What interest was taken by the practical Bessemer steel manufacturers of the different companies in these reports so issued by Mr. Holley, if you know?

A. They received most careful consideration at their hands and from time to time, and when deemed advisable, the American practice was altered in view of the information so furnished. These reports were regarded by the various organizations as most valuable ones and upon their receipt were given most serious consideration. They were naturally of great interest to the officers of the various works who were directly responsible for their operation, and
448 furnished the basis for consultation between such of them as were on intimate terms.

59 Q. You have referred to Captain Jones coming to the Edgar Thomson steel works in 1873. How long did he remain there and what was his position while he was connected with that company?

A. When he first went to the Edgar Thomson they were in process of erection and his duties were mechanical in character, but practically upon their completion he was given charge of the manufacture of the steel produced by them, and so remained up to the time of his death.

Q. 60. Do you know what became of Mr. Holley's library subsequent to his death?

A. It passed into the possession of the Rensselaer Polytechnic Institute of Troy, N. Y., immediately upon the settlement of his estate. I feel quite positive that one of the provisions of his will was that such disposition should be made of his library, including his drawings, reports, etc.

Q. 61. Have you had any connection with that Rensselaer Insti-

tute at Troy to which you refer and, if so, what and during what period of time?

A. Yes, sir, I am one of the trustees of that institution and have been since 1885. I am not positive of the exact date.

Q. 62. Were you acquainted with that institute and its library before you became one of the trustees?

A. Yes, sir.

Q. 63. Can you state whether that library has been open to the public, and, if so, how long has it been, to your knowledge?

A. I have been familiar with the workings of the Rensselaer Institute ever since I located in Troy, in 1873, and during all of that time it has been open to the public; in fact, it has always been recognized as a public library of reference and I have personal
449 knowledge of my subordinates, while I was in charge of the Troy works, having frequently so used it.

Q. 64. I call your attention to this article, entitled "Direct use of blast-furnace metal in the Bessemer practice," copyright by Mr. Holley, 1877, and ask you to state what bearing it had upon the method described in the Jones patent in suit?

A. In this article Mr. Holley clearly outlines the principle of the Jones patent, and this is very manifest in the 4th clause on page 4 of pamphlet, which is as follows:

"The obvious remedy is to mix a number of blast-furnace charges so as to reduce the irregularity to a minimum. Two systems of doing this are on the eve of trial; the one is simply mixing so few charges in a tank that the metal will be drawn out before it chills; the other is to store a larger number of charges in a heated tank—that is to say, in an immense open-hearth furnace."

Mr. Holley gives an elaborate report of the practical operation of the direct-metal practice at West Cumberland, Barrow, the Dowlais and Ebbw-vale works, and refers to previous reports in which he has described the French and Belgium practice. To these I have previously referred in discussing the Terre Noire practice. He states that Mr. Snelus in seeking to obtain a more uniform metal "was about trying the experiment of placing a 20-ton ladle on a hydraulic lift so arranged as to store, mix and pour, say three 6-ton to 7-ton blast-furnace taps, or to mix blast-furnace and cupola metal." He stated further that he had no doubt the metal would keep hot, as the ladle was to be thickly lined and well covered. In the quotations and references which I have mentioned in Mr. Holley's report under consideration, in my judgment, the process claimed in the Jones patent is clearly outlined. There is another part in Mr. Holley's report which is under the head of "Unfinished works," upon which he reports as follows:

"The most unique Bessemer works I have ever seen is
450 nearly completed at Moss Bay, a suburb of Workington. The vessels stand side by side and high, so that there is no pit. In front of them there is, not a ladle crane, but a high-jib hydraulic crane. This crane, by means of a yoke, lifts the ladle of iron to the vessel nose, and it also, by means of a yoke, holds the steel ladle under the vessel nose while pouring, and then transfers

it to the ladle crane, which stands at one side. On the other side, standing upon the general floor there is to be a 60-ton reverberatory, coal-fired furnace, or else there will be two 40-ton furnaces—this point had not been settled when I was there, although the rest of the plant was nearly done.

"The blast furnaces are about 1,000 feet away and the direct-metal railway runs into the converting works at one side of the vessels on the general level. From this point the direct-metal ladle may be lifted to the vessel by the high-jib crane as before described, and tipped into the vessel. Or by means of another lift or crane (not yet constructed), the ladle may be lifted to such a height that its contents may be tapped out into the large reverberatory furnace. In this furnace it is the intention to store and keep hot some 60 tons of iron from all the blast furnaces. The vessel charges will be tapped out as required into a ladle, raised by high jib crane, and poured into the vessel.

"Although this large furnace may be the best means of mixing metal so as to get a uniform result, the complex manipulations due to the arrangement described seem likely to take an unnecessary amount of time and labor. The metal is lifted four times before it is run into the ingot moulds—once to the big furnace, once to the vessel, once to the ladle crane, and once by the ladle crane. And it is going to be a somewhat difficult matter to stop the tap-hole of a furnace with 50 tons of fluid metal behind it. Of course, the ferrostatic pressure may be made small by keeping the bath shallow, and the great surface thus exposed would be favorable to heating the metal. I am promised an early account of the results of this experiment."

It is clear that in this plan the storage reservoir in which the metal was to be kept hot is described. While Mr. Holley criticises the mechanical means employed, he is very emphatic in
451 recommending the process. Later in drawing his conclusions from the report he uses the following language:

"But if the storage of a large quantity of iron in a reverberatory furnace or other reservoir should prove successful, then a few blast furnaces making even an irregular product, and, if necessary, working in connection with cupolas, would largely economize the Bessemer manufacture.

In fact, this mixing of irregular irons on a very large scale, thus avoiding the expensive niceties of ore selection and the necessities of many furnaces, is the theoretical key to the situation. When the way to its successful adoption is demonstrated, the direct process will undoubtedly have great advantages, even over the present practice on the Continent, which employs manganiferous ores. But until this large scale mixing is developed, it should not appear that the use of our comparatively irregular blast-furnace metal, and more especially the use of part blast-furnace and part cupola metal, can result in any substantial saving.

But the mixing problem is not such a difficult one. A small amount of flame, spread over a large surface of metal should certainly keep it hot for a long time, seeing that the metal will keep

hot in a ladle exposed to the air for an hour or more. And should there be any trouble about stopping the tap-hole in a large storing furnace, it would not be a very difficult or expensive matter (considering the Pernot revolving-hearth experience) to tip the whole hearth enough to pour a charge."

In the above, to my mind, Holley most clearly pointed out the advantages and practicability of the process claimed in the Jones patent; and, in fact, went further in this, as he anticipated the very means later employed by Captain Jones.

Q. 65. I call your attention to United States patent to James P. Witherow, No. 315,587, April 14, 1885, and ask you as a practical metal-worker as to what bearing this patent has upon the Jones suit?

A. I consider that it has a very strong bearing on the Jones patent, as it was a practical device for accomplishing the
452 storing in an intermediate vessel the direct metal to be subsequently used in the pneumatic process for making steel.

Q. 66. Please look at the With-row patent, No. 327,425, dated September 29th, 1885, and state what bearing it has upon the Jones patent in suit.

A. Witherow clearly points out the desirability of using blast-furnace or direct metal in the converter and also goes fully into the relative amount of metal which it is most desirable to take from a blast furnace at each time of tapping and the quantity to be used in a converter, based on which he provides an intermediate ladle, covered and provided with heating means of sufficient size to receive and store the excess of metal from the blast furnace, from which the smaller quantities required for the converter are to be taken from time to time as required.

Q. 67. From your examination of this second Witherow patent, what is your opinion as to whether it discloses a practice which would lead to or require the tapping of one charge of blast-furnace metal into metal remaining in the intermediate storage chamber?

A. That undoubtedly would have happened in the operation of the proposed apparatus, and both from the wording of the specifications and the drawings accompanying them, it is very evident that Witherow expected it to operate in that manner. In the successful running of a blast furnace it is very important that the smelting operation should be interrupted as infrequently as possible by taking off the blast, and, as in subsequent treatment of the metal in the converter there are frequent delays from various causes, it was evident that one of Witherow's principal objects was to provide a receptacle of sufficient size and properly protected in which the metal could be successfully stored, and thus not bring about interruptions of the operations of the blast furnace.

453 Q. 69. Are you acquainted with James P. Witherow, the patentee named in the last two patents commented upon?

A. I am, and have been for a great many years.

Q. 69. What is his business?

A. For many years he was a blast-furnace manager. Later, designer and constructor of furnaces, rolling mills and steel works.

He is one of the owners of the Clapp Griffith pneumatic steel process for America. He has been quite a prolific inventor in both iron and steel metallurgy.

Q. 70. Suppose a case in the manufacture of steel in which pig metal is remelted in several cupolas, say from 3 to 5, and is run therefrom into a large receiver or ladle, holding, for example, 35,000 pounds of molten metal by means of a common runner leading from all the cupolas, which ladle is filled at times to its entire capacity and from which converter charges, say from 14,000 to 17,000 pounds would be withdrawn at intervals as needed leaving remaining in the ladle after withdrawing such charge from 5,000 to 20,000 pounds into which metal so remaining metal was again tapped from the cupolas when the cupolas were ready for tapping and the supply for conversion so kept up, what bearing would this practice have upon the Jones patent, if prior thereto?

A. It certainly would have anticipated the claims of the Jones patent so far as the equalization and mixture of the varying qualities of the molten metal were concerned.

Q. 71. Would it make any difference, in your opinion, as a practical Bessemer manufacturer, whether it was carried out with cupola metal from several cupolas, or carried out with blast-furnace metal from several blast furnaces?

A. I have in my previous testimony, I think, fully explained this.

Q. 72. As affecting the principle of mixing two or more non-uniform cast irons is there any any difference whether or not
454 metal from a previous charge is left in the ladle, or two streams of ununiform metal are introduced into the ladle?

A. There is no difference in the principle. You may get more satisfactory results simply because you will have a greater amount of metal and hence minimize any non-uniformity which may result from the operation. You would accomplish the same thing by increasing your number of streams of metal flowing into your receptacle.

Q. 73. Suppose a case in connection with foundry practice for the manufacture of car wheels in which three cupola furnaces are employed which are tapped into a large ladle holding from 12 to 15 tons and from time to time small charges of about 600 pounds are withdrawn from this large ladle without entirely emptying the same, and the metal is subsequently tapped from cupolas into the metal remaining in the large ladle, what bearing would such practice have upon the method of the Jones patent, if prior thereto?

A. In my judgment, it would clearly anticipate it because it is practically performing the same operation.

Q. 74. Mr. A. M. Moreland, a witness for the complainant company, testified that there was a saving of an average of 65 cents per ton of ingots produced between the Jones mixer process, the method described in the patent in suit, and the cupola process. He was then asked:

"Q. 4. Please give us an itemized statement of how this saving takes place?

"Answer:

"By saving in loss of metal in melting in cupolas, and blowing converters	25c. per ton
"Labor at cupolas	20c. per ton
"Expenses, repairs and supplies	5c. per ton
"Coke and limestone	15c. per ton

"These figures make up the 65 cents."

Please state whether any of these expenses would be incurred in using direct metal, that is, molten metal taken from the blast
455 furnace and introduced while still molten into the converter in any of the ways which have been set forth in the patents or publications to which you have referred?

A. No, sir; Mr. Moreland makes up his savings from the avoidance of loss of melting in the cupola, which, of course, would not take place, no matter how the metal was handled, providing it was used direct from the blast furnace. Again, he is unfair in estimating the labor saved at the cupolas. Likewise the expenses, repairs and supplies, was not the same, and in the coke and limestone used in them, he is emphatically wrong, because there are no cupolas used when direct or blast-furnace metal is treated.

Q. 75. Considering the different ladles or reservoirs which have been described in the various patents and printed publications, and not regarding questions of mere construction of apparatus, is there any advantage as a process or method in the supposed invention of the Jones patent set forth in such patents or publications?

A. No, there can't be, as I have already given my opinion that they are practically the same thing.

Q. 76. Then considering what is described in this Jones patent, the apparatus and all, what advantage, if any, would be found in the use of the same?

A. I consider Mr. Jones' apparatus a valuable construction. As to whether or not it is patentable as an apparatus I do not know. It is the process which I have been criticising. The mechanical part of the proposition was a great credit to him as an engineer.

Q. 77. Have you seen in operation any of the mixing reservoirs employed in this country, and if so, which?

A. I have seen those at the Edgar Thomson works of the Carnegie Steel Co. and the South Chicago works of the Illinois Steel Co.

Q. 78. As these reservoirs were constructed was there any means employed for heating them?

A. Yes, at both places. They were so constructed that flame from either gas or oil was introduced between the surfaces of
456 the molten iron and the reverberatory roof of the receptacle.

Q. 79. For what purpose was this flame introduced?

A. To maintain the heat of the molten liquid underneath it.

Q. 80. In this connection I again call your attention to the description in the 1877 Holley article as to the works at Moss Bay, where a "reverberatory coal-fired furnace" was to be used and to the criticism on the part of Mr. Holley of such furnaces as found on the last page of that article, to wit:

"A small amount of flame spread over a large surface of metal should certainly keep it hot for a long time, seeing that the metal will keep hot in a ladle exposed to the air for an hour or more."

Please state your opinion as to the similarity of such construction with what you saw at the Edgar Thomson and South Chicago works as to the way of heating the reservoirs there in use.

A. Mr. Holley emphasizes the effect of the spreading of flame over the surface of the melted from in a reverberatory furnace, and in my judgment it does not make any practical difference whether that flame comes direct from coal-firing or is introduced from natural gas, as at Edgar Thomson, or oil, as at South Chicago. He depends upon the reverberatory effect of the roof of the furnace which is the same as the effect obtained in the receptacles at the Illinois Steel Co. and the Carnegie works It was natural that a coal-fired furnace should have been depended upon at the time Holley wrote, certainly in England, as neither natural gas nor petroleum were available. Where the gas and petroleum were obtainable their use was more convenient and economical.

Q. 81. I call your attention to the cupola practice of tapping the metal from several cupolas into a mixing ladle or reservoir
457 before the metal is withdrawn for conversion or other use, and to the use of the mixing reservoir in connection with direct metal taken from the blast furnaces. In which of these two cases is it more desirable, in your opinion, to employ the mixing ladle or reservoir, cupola practice or the direct-metal practice?

A. I think the history of the Bessemer processes has proven that the use of the mixing ladle or accumulating reservoir between the cupolas and the subsequent employment of that metal is of greater importance than the accumulating reservoir between the blast furnace and the subsequent use, for several reasons. Certainly the introduction of that ladle in the American Bessemer practice did more to send it ahead of the rest of the world than almost any other one invention. Again, a great advantage of such a reservoir is making the various departments of the establishment, to a certain degree, independent of each other. If you do not have such a reservoir in the cupola practice and delays occur in the converting works, it would necessitate taking the blast off of the cupolas, and should such delay extend over a considerable period of time, the melted metal in the hearth of the cupola would either chill up and render it necessary to drop the bottom of the furnace, or else it would have to be tapped off in some inconvenient manner, and thus become awkward to handle as scrap. On the other hand, when running on direct metal, should delays occur at the converting works, the metal from the blast furnace can be cast into pigs of commercial and uniform size and shape, which could be subsequently melted in cupolas or used for other purposes, and thus the regular working of the blast furnace not be disturbed. Moreover, in most cupola practice a great variety of metals are used, varying greatly in both their physical and chemical characters, and it is often the case that it is through such mixture in the cupola that metal is utilized which could not have been used at all if taken

direct from the blast furnace. That is, should the blast furnace have been working so badly that the produced iron was unfit
458 for the Bessemer practice it would be homeopathically mixed with better materials in the cupola, which, after melting would be averaged up in the accumulating cupola ladle, and thus ultimately make good steel. I have in a previous answer explained that the metals in the cupola furnace do not melt evenly. It must be remembered also that great progress has been made in blast-furnace practice, so that under normal conditions the metal can be held very uniform. When such normal conditions are interfered with the cupolas or cupulating ladle furnish the means to take care of the unsatisfactory metal, as above referred to.

In my judgment the most essential part of the reservoir in either the direct-metal or the cupola-metal practices, is the absolute controlling of the quantity converted, by the provisions which it provides for the charges to be weighed before being placed in the converters.

Cross-examination by Mr. BAKEWELL:

X Q. 82. In answer to Q. 77, when asked whether you had seen in operation any of the mixing reservoirs employed in this country, and if so, which, you specify those at the Edgar Thomson works of the Carnegie Steel Company and the South Chicago works of the Illinois Steel Company. Are these all of the mixing reservoirs which you have ever seen in use?

A. If you mean in contradistinction to ladles so used, yes, sir.

X Q. 83. And what distinction do you draw in your last answer between reservoirs and ladles?

A. As applied to this case, I distinguish the reservoirs from ladles by being in fixed location and by being covered with a reverberatory roof or its equivalent.

X Q. 84. And what difference does this make in your judgment?

A. It makes differences as to the quantity of molten metal which can be held in a reservoir and the length of time that it can be kept fluid.

459 X Q. 85. What do you mean by the word "reverberatory" as used in your answer?

A. Of performing the office of casting down or reflecting upon the molten metal heat which may be introduced over or above such bath or metal.

X Q. 86. By that I understand you to mean heat introduced into the vessel independently of the heat of the molten metal itself, am I right?

A. You are.

X Q. 87. Then do I understand you as stating, of your own knowledge, that the mixing reservoir or reservoirs used at the Edgar Thomson works in the practice of the process of the patent in suit are reverberatory in the sense in which you have used that term in your testimony?

A. I so consider them.

X Q. 88. Supposing such not to be the fact, would that make any change whatsoever in the testimony you have given? I mean, supposing it to be the fact that the patent in suit does not call for the use of a reverberatory gas mixer?

Defendant's counsel asks what is meant in the question by "the testimony you have given." The question is certainly indefinite as not indicating any particular part of the testimony, while it can hardly be presumed that it includes the whole.

Counsel for complainant replies: My meaning is this: The witness has testified in regard to the process described and claimed in the patent in suit, and has referred in his testimony to supposed anticipation of that process involving the use of certain apparatus; what I want to know — whether such testimony is given on the supposition of the witness that the patent in suit calls for the use of a reverberatory mixer and that the process as actually used by the complainant company involves the use of a reverberatory mixer. And also further, if a reverberatory mixer is neither called for by the patent in suit nor used by the complainant company in
460 the practice of the process therein described, such facts would have made any change whatsoever in the testimony he has given in this suit. Of course I do not refer, as defendant's counsel seems to imply, to any other testimony of the witness in any other suit.

The question, with its explanation, is objected to as indefinite, as including several questions and it is the purpose of the question to ask for a review of all the different anticipations referred to in the entire examination of the witness, it is suggested that the witness be permitted to take his testimony, and the different publications referred to therein, and answer as to them seriatim.

Counsel for complainant desires the witness to answer the question or not answer it, as he sees fit or may be instructed by the counsel for defendants.

The witness is instructed by defendant's counsel to use his best efforts to answer the question, and is further instructed that if he desires to do so, he is entitled to look at his direct examination and the defenses referred to therein.

A. You asked me where I had seen certain apparatus in use, and following my answer you asked me to describe the difference between the mixers or storage furnaces employed by the Illinois Steel Co. and the Carnegie Steel Co., and receiving or accumulating ladles. It was in trying to describe that difference that I applied the term "reverberatory furnaces," or used the term "reverberatory" I formed my opinion from my own observations and knowledge, and utterly regardless of any claim of the patent in controversy.

X Q. 89. Am I to understand that in your opinion it makes no difference whatsoever whether the mixer is a reverberatory one or not?

A. I do not quite understand what you mean by your question. If you mean one which is not reverberatory would be equally effective in practical operation with one which is, I certainly think it would

make a difference, as the fact of the covering of the mixer with a reverberatory roof certainly will enable the keeping of the
461 metal fluid much longer than if not so covered; so far as the mere mixing of the metal is concerned, it would not, in my judgment, make any difference whether it was covered or not.

X Q. 90. When did you first, if ever, see the operation of the direct converter process at the Cambria works?

A. I have never seen it.

X Q. 91. In your answer to Q. 19 you have stated your interpretation of the invention claimed in the patent in suit. Am I to understand that you consider that to be a full and correct definition of the process claimed in that patent?

A. I so intended it.

X Q. 92. And I may understand that the testimony which you have given in this suit is based on the understanding on your part that that is the correct definition of the invention described in the patent in suit?

A. I should say it was, as I based my answer, as I understand the claim of the patent, as stated in its specification.

X Q. 93. In your interpretation or definition of the invention of the patent in suit given in answer 19, have you taken into consideration the clause in the 2d claim, in the following words: "The process of introducing into a mixing receptacle successive portions of molten metal ununiform in their non-metallic constituents (sulphur, silicon, etc.), removing portions only of the composite molten contents of the receptacle without entirely draining or emptying the same, and successively replenishing the receptacle with fresh ununiform additions"?

A. I certainly did, sir, and do not see how that 2d claim in any way affects the truth of my answer.

X Q. 94. Do you mean to testify that all the supposed instances of use of the process of the patent in suit, which you have referred to in your testimony in this case, make use of the process referred to in my last question, to wit, the successive introduction into a receptacle of portions of molten metal and removing from
462 time to time portions only of such metal, and the successive replenishing with ununiform additions?

A. I cannot say that all of the references which I have made cover such an operation, but a number of them do, as the practice is as old as the Bessemer practice in America.

X Q. 95. Will you kindly specify the instance or instances which you have referred to in your testimony-in-chief in which the process referred to in my 93rd question is described?

A. My answer to Q. 39 in which I refer to the Deighton patent; also in answer to Q. 46, where I refer to Mr. Snelus' description of Bessemer practice in America, as published in the Journal of the Iron and Steel Institute for the year 1874, pages 348 to 367 inclusive; again in answer to Q. 47, where I give statement by Mr. Bessemer as published in the Journal of the Iron and Steel Institute for 1876, pages 12 to 42; again in answer to Q. 49 where there is given a description of the Bethlehem, Pa., practice as given in the Journal

of the Iron and Steel Institute for 1878, pages 121 to 137, also page 144; again in answer to Q. 64 referring to an article of Mr. Holley's copyrighted by him — 1877; again in answer to Q. 66, where I discussed the Witherow patent No. 327,425, dated Sept. 29, 1885; the answer to Q. 9 in relation to the practice at the Cambria Iron Co.'s works then under my charge; also in answer to Q. 10 in the same connection; in answer to Q. 14 in the same connection; answer to Q. 15 in regard to my practice in charge of the Troy works following the year 1873.

X Q. 96. Taking all the cases which you have referred to in your last answer involving printed or written descriptions of processes, do you mean to testify that they all of them describe the introducing, removing and replenishing, successively and continuously of molten metal into and from a receiving vessel, substantially as described in the patent in suit?

463 A. I consider that the process, but I should rather call it practice, as described for the early Cambria days the Troy practice; the Deighton practice; the Bessemer practice; the practice described by Snelus; that outlined by Holley in his 1877 paper, and the proposed Bethlehem ladle clearly outline such practice.

X Q. 97. Question is repeated and the witness is requested after carefully considering it to give a categorical answer.

A. I decline to answer the question unless I am at liberty to give my reasons applying to each case. If permitted to do that I will do my best to answer the question.

X Q. 98. Please point out and quote the passage in the Deighton patent which you have referred to which describes specifically the process referred to in X Q. 93?

A. I so interpret the following clause in which is stated—

"My invention also consists in taking the molten metal directly from the blast furnace to the converter, in which case I prefer to arrange the Bessemer plant in a line at a right angle to a row of two or more blast furnaces and place a vessel to receive the molten metal tapped from two or more blast furnaces to get a better average of metal which will be more suitable for making Bessemer steel or metal of uniform quality, the vessel or receiver being placed on a weighing machine so that any required weight may be drawn or tapped from it and charged to the converter."

In forming my opinion I take into consideration the drawing accompanying the patent and my knowledge of the art, which convinces me that Mr. Deighton expected to keep the metal running in his receptacle from his blast furnaces at intervals regardless of when it was taken out for use in the converters, which, to my mind, means continuous running.

The witness is desired in future when replying as to the references to confine himself as the question asks to the specific words of the printed or written matter which describes the process.

464 If the above request of complainant's counsel is intended to require the witness to omit any comment whatever upon the portion quoted from any patent or publication or to omit the

use of his own knowledge of the Bessemer practice at the time the patent was issued or the publication made, he is instructed that such requirement is improper, as all such patents or publications are addressed to those skilled in the art, and as a skilled Bessemer steel manufacturer, he is entitled to use his knowledge of the art in interpreting such patents or publications.

Counsel for complainant replies that the witness is not asked to give his interpretation based upon the subsequent state of the art, or his personal knowledge of the art subsequent to the date of the patent and to use his imagination in supplying what is lacking in the specification of the patent, but to confine his answers to a quotation of the passages which he supposes to contain a description of the process of the patent in suit.

Defendant's counsel calls attention to the statement in his objection to the request of complainant's counsel of—

"His own knowledge of the Bessemer practice at the time the patent was issued or the publication made."

And calls attention of the court to the fact that nothing was found in his objection of—

"Knowledge of the art subsequent to the date of the patent or imagination."

X Q. 99. How would you remove from apparatus such as is described in the Deighton patent slag, kisch, etc., which necessarily accumulates in a vessel containing molten pig metal without discontinuing the charging of the vessel and emptying the mixer?

A. If the receiver was run well up to its total capacity the slag, etc., could be pulled over the top of its sides. Undoubtedly, in fact positively, times would come when it would have to be emptied and its use discontinued, which would naturally lead to works
465 being equipped with more than one such receptacle, so that the second one should be used while the first was being repaired.

X Q. 100. The passage which you have quoted from the Deighton patent is the only passage which you can refer to as describing specifically the removing of portions only of the molten contents from the receptacle and successively replenishing the receptacle with fresh ununiform additions, is it not?

A. I find the following words which perhaps apply, "system or mode of arranging and working the Bessemer converters with the receiver or receptacle *m*, for mixing the molten metal from two or more smelting furnaces to get a more uniform quality of metal, substantially as hereinbefore described and illustrated by the drawings."

X Q. 101. And do you mean to say that that describes specifically the removing portions only of the molten contents of the receptacle without entirely draining or emptying it and successively replenishing the receptacle with fresh ununiform additions?

A. No, sir, those words alone do not, but it is from their reference to "as hereinbefore described and illustrated by the drawings" from which I made the application in forming my opinion.

X Q. 102. I do not want your opinion, but I do want to know whether you are willing to testify that as a matter of fact the two passages quoted by you or either of them, specified or described the operations referred to in my last question.

Defendant's counsel understands that the witness is called as a skilled Bessemer-steel manufacturer, and does not see how he is expected to testify unless he gives his opinion.

Complainant's counsel replies that the witness when asked an expert question may give his opinion, but asked to point out
466 the passage in a patent which describes a certain process or operation he is bound to either point out such passages or to admit that they do not exist.

Defendant's counsel objects to the attempt on the part of complainant's counsel to prevent the witness from expressing his opinion as to the meaning to him, as a skilled metallurgist, of the meaning of the language quoted when the witness is called simply and solely for that purpose. If complainant's counsel wants the quotation of parts of patents, it is suggested that he can do this as well in his brief as make the witness do it. The purpose of calling the witness, and he presumes the cross-examination, being to find out the witness' opinion and not to make him do the perfunctory work of quoting passages from patents.

A. I am sorry I cannot make my mind operate as you desire. It is impossible for me to read a description of a process of which I am familiar without forming an opinion. I think it very probable that if the Deighton patent were read by one unskilled in the art they might be at a loss to understand all of its proposed workings.

X Q. 103. When did you become familiar with the practice of the Deighton patent, as you have implied in your last answer?

A. I never saw the Deighton patent, to the best of my recollection, until some time in the early part of this year, although I was familiar with the general scheme as a matter of technical history, but was ignorant as to his claims of detail for his proposed plans; in fact, I am almost certain that I knew of such a scheme without having associated it with any individual's name.

X Q. 104. Will you please quote the passage you referred to in your 95th answer as a description by Mr. Snelus, which you are willing to testify describes the various steps of the process of the 2d claim of the patent in suit?

467 A. Mr. Snelus stated—

"That there was no inseperable difficulty in running iron direct from the blast furnace into the converter. By running it into a separate vessel as they did in America, they could then deal with it as they liked. The plan in all the works in America was to melt in a cupola continuously, and then to run the iron into a ladle which was balanced, and held from 10 to 12 tons. From that the 6-ton charge was run direct into the converter. They wanted an intermediate vessel between the blast furnace and the converter."

X Q. 105. What period of time is referred to by Mr. Snelus as

being that at which the practice referred to in your quotation was used?

A. 1873 and 1874.

X Q. 106. Now, will you please give me a quotation from Mr. Bessemer's statement published in the Journal of the Iron & Steel Institute for 1876, pages 12 to 42, which describes specifically the process of the second claim of the patent in suit, with its several steps?

A. He stated, "he had, himself, proposed the tapping of three furnaces into one ladle or receiver, and when he advised some of his friends, in the company with which he was connected in the neighborhood of Barrow, to come into steel-making, they arranged their work, some two years ago, so that the pig iron could be tapped onto a ladle, or rather into spherical vessel with an almost close top to it, that would hold 30 tons. It was proposed to make at least three 7-ton tappings into that vessel, and to move it on wheels into the converting house, using a pair of converting vessels, one after the other, until the four charges of five tons each were worked off; having the second ladle or vessel on its journey to supply so as to keep on working continuously."

Adjourned to meet at same place tomorrow at 10.30.

468 Met pursuant to adjournment.
Present: Counsel as before.

Cross examination of Mr. HUNT continued:

X Q. 107. Do I understand you that the passage which you have quoted from Mr. Bessemer's statement on page 24 of the Journal of the Iron and Steel Institute for 1876, contains a full statement and description of the entire process described in the patent in suit and referred to in the 2d claim?

A. It certainly to my mind describes practically the same process, as he outlines a continuous working and the leaving of metal in the receptacle into which other metal is to be tapped.

X Q. 108. Can you explain why if that statement contains a full description of the invention of the patent in suit, the invention never got into public use until introduced by Capt. Jones, the inventor, and described in the patent in suit, that is, during a period of eleven years?

Question objected to as assuming a condition of facts which are not only not proven, but which are negatived by the testimony in the case, as shown by the numerous proofs of prior use, such for example as the employment of accumulating ladle in practically all the Bessemer works in the country, the employment of fixed mixing ladles, such as at Whitney's, and at other car-wheel works, the mixing of direct metal at the South Chicago works and at complainant's own works and other prior uses not necessary to mention.

Counsel for complainant calls the attention of the counsel for defendants to the fact that he has no right to insert an argument in

the record under the guise of an objection, which however proper it might be in a brief, is highly improper in this place and especially in the presence of the witness who is being examined.

469 To which defendants' counsel replies that it is perfectly proper in view of the evident misstatement of fact contained in the question.

A. I do not recognize such to have been the case.

X Q. 109. In your answer to Q. 95, you also cite an article from the Journal of the Iron & Steel Institute for 1876, where there is given a description of the Bethlehem, Pa., plant. State whether that, to your mind, describes fully the invention of the patent in suit, and point out specifically the words of the reference which describe the Jones invention as set forth in the 2d claim?

A. To my mind the process is indicated by the following words of Mr. Snelus:

"He believed it would be found that the great advantage the Bessemer works in America had was the intermediate receiving ladle which was designed by Mr. Holley, and which was universally used there."

And afterwards the same gentleman said:

"No one in England as far as he knew, was using any intermediate receiver between the blast furnace and the converter. He thought himself that the receiver was of considerable importance, both for saving time and facilitating the admixture of iron; and he was confirmed in that belief by the idea of Mr. Fritz, of Bethlehem, who was about putting up a thirty-ton ladle, according to Mr. Holley, to receive the metal from the blast furnace, and hold it in readiness, so that at a moment's notice, you could take your iron into the converter, and also obtain a better mixture."

With my knowledge of the state of the art at the time of this statement by Mr. Snelus, I consider it to have pointed out practically the same process.

X Q. 110. You have stated, as I understand, that you consider that the Deighton patent, specification and drawing, describes an intermediate receiver between the blast furnaces and the converter; this patent was granted in 1873. Is it not manifest from the quotation which you have made either that Mr. Snelus did not

470 regard the Deighton contrivance in that light, or that the thing had never been used to his knowledge in England?

A. As Mr. Snelus does not refer to the Deighton patent or device, I have no means of knowing whether or no he was cognizant of it. From his statement it would appear to me that if it was in use at the time of his statement, he was unaware of it, his statement being made in 1878.

X Q. 111. You have, as I understand, stated that you were very generally acquainted with the state of the art and practical application of the Bessemer process, and also for what is known as the direct process, as carried on with the Bessemer apparatus in this country. Are you not aware that at the Bethlehem works to which you have referred, they never had a mixer that they did not mix

metal from several blast furnaces, and that they finally abandoned the use of the direct process?

A. I am aware that they abandoned the use of the direct process after having carried it on for some time, and so far as I recollect they did not mix metal from several blast furnaces in a ladle or receiver, but they did use intermedirte or cupola ladles. And it was a peculiar part of that plant that the cupola ladle or ladles were not in a fixed position, but were hauled from the several cupolas by a locomotive to the converters.

X Q. 112. In your answer to the 109 X Q. in which you quote a passage referred to you in your 95th answer, in which you quoted the words "Mr. Snelus," I want you to say as an experienced practical steel manufacturer and mechanical engineer, in which capacity you have in your answer to the 19th question, given your understanding as to the invention covered by the patent in suit, whether or not you regard the passage quoted in the answer to the 109th question as a full, accurate and sufficient description of the entire invention described in and covered by the Jones patent in suit?

471 A. Mechanically it certainly is not a full description, but metallurgically it certainly points out the use of a receptacle intermediate between the blast furnaces and converters holding several converter charges, and which certainly conveys to my mind as a steel-maker the intention of securing more uniform metal, both as to quality and supply, which, if I rightly understand the patent in suit, is all that is claimed for it.

X Q. 113. I now refer to you the article by Mr. Holley which you speak of in your answer to Q. 94 and ask you to point out as briefly as you can, and quote that part of the article which, in your judgment, fully describes the invention of the patent in suit as described in the specification and specified in the claims?

A. Mr. Holley in his copyrighted article of 1877 says:

"The obvious remedy is to mix a number of blast-furnace charges, so as to reduce the irregularity to a minimum. Two systems of doing this are on the eve of trial; the one is simply mixing so few charges in a tank that the metal will be drawn out before it chills; the other is to store a larger number of charges in a heated tank—that is to say, in an immense open-hearth furnace." He later in the article describes the practice about being inaugurated by Mr. Snelus as follows: That he "was about trying the experiment of placing a 20-ton ladle on a hydraulic lift, so arranged as to store, mix and pour, say 3 six-ton to seven-ton blast-furnace taps, or to mix blast-furnace and cupola metal." He states his certainty that the metal would keep hot. He also describes a works which he saw being built at Moss Bay in the following language: "On the other side, standing upon the general floor, there is to be a 60-ton reverberatory, coal fired furnace, or else there will be two forty-ton furnaces—this point had not been settled when I was there, although the rest of the plant was nearly done."

"The blast furnaces are about one thousand feet away, and the direct-metal railway runs into the converting works at one side of

the vessels on the general level. From this point the direct-
472 metal ladle may be lifted to the vessel by the high-jib crane, as before described, and tipped into the vessel. Or, by means of another lift or crane (not yet constructed), the ladle may be lifted to such a height that its contents may be tapped out into the large reverberatory furnace. In this furnace it is the intention to store and keep hot some 60 tons of iron from all the blast furnaces. The vessel charges will be tapped out as required into a ladle, raised by the high-jib crane, and poured into the vessel."

After criticising the mechanical arrangement of the plant, he goes on to say:

"But if the storage of a large quantity of iron in a rever-atory furnace or other reservoir should prove successful then a few blast furnaces making even an irregular product, and, if necessary, working in connection with cupolas, would largely economize the Bessemer manufacture.

"In fact, this mixing of irregular iron on a very large scale, thus avoiding the expensive niceties of ore selections and the necessity of many furnaces, is the theoretical key to the situation. When the way to its successful adoption is demonstrated the direct process will undoubtedly have great advantages, even over the present practice on the continent, which employs manganiferous ores. But until this large scale mixing is developed it should not appear that the use of our comparatively irregular blast-furnace metal, and more especially the use of part blast-furnace and part cupola metal, can result in any substantial saving."

"But the mixing problem is not such a difficult one. A small amount of flame, spread over a large surface of metal, would certainly keep it hot for a long time, * * * and should there be any trouble about stopping the tap-hole in a large storing furnace, it would not be a very difficult or expensive matter (considering the Pernot revolving-hearth experience) to tip the whole hearth enough to pour a charge."

The foregoing answer is objected — in so far as it is a repetition *in extenso* of what the witness has already said in answer to Q. 64, whereas the present question called only for a brief quotation of that part of the article which fully described the invention of the patent in suit.

473 Counsel for defendant replies that the answer of the witness consists in quotations from the publication to which his attention was directed in the question and it is therefore apparently responsive and proper.

X Q. 114. The passage which you have quoted from Mr. Holley's report, and which is also given more fully in your answer to Q. 64, is a quotation from that part of the Holley report which is headed "Unfinished work," is it not?

A. The part where I described the proposed storage furnace does come under that head.

X Q. 115. To the report itself which is dated June, 1877, there is appended the following note:

"NOTE.—This report is printed, not as a publication, but simply for the convenience of my clients and their exclusive use."

Is it not?

A. There is such a note.

X Q. 116. And I further ask you whether, in your judgment as an expert metallurgist and mechanical engineer, this statement of a proposed experiment which, so far as the report shows, was never carried into actual use, contains a full, complete and accurate statement and description of the invention described and claimed in the patent in suit? I do not refer to any inferences which you may choose to draw from the statement, and I ask you if possible to carry your mind back to the year 1877 and to the knowledge which then existed in the art of the Bessemer process, and especially of direct Bessemer process, in answering the question.

Objected to for the reason that the publication referred to is for the purposes of this case to be read in connection with the art as it existed down to the date of complainant's patent. The witness is also instructed in answering the question to note the fact that the patent in suit is for method or process and that the ap-
474 paratus therein shown is expressly disclaimed as being the subject of a separate application for patent.

Complainant's counsel calls attention of the witness to the fact that the question he is asked to answer has reference to the invention described and claimed in the patent in suit.

A. I think I can easily put my mind back as you direct, as I was so familiar with the circumstances attending not only this, but all of Mr. Holley's reports to his clients; and moreover, in the paper itself, he so distinctly refers to the difficulties then existing in the direct metal process which led him to suggest ways to overcome them, and to my mind, he clearly outlines the process or method in controversy.

X Q. 117. Witness is requested to answer the question, and to testify whether in his experienced judgment, the description in the Holley paper contains a full, specific and particular description of the Jones invention as described and claimed in the patent in suit. I did not ask as to what Holley's report indicated but as to whether it particularly and specifically describes the Jones invention.

A. Holley's report is not worded as a description of a patent, but he distinctly describes the way to overcome the difficulties which were then recognized as existing in the use of direct metal, and in so doing, to my mind, clearly points out the process as described in the patent which we are now considering.

X Q. 118. Is it not a fact that since the year 1877 when the Holley report was written and distributed to his clients, but specifically not published, down to the time of the application of Wm. R. Jones, in Oct., 1888, for the patent in suit, the difficulties in the use of the direct Bessemer process were frequently referred to and still recognized as existing in the art and that very many attempts were made, some of which were patented, to overcome these difficulties,

but none of which ever came into actual successful opera-
475 tion, and all of which, whether patented or not, must therefore be regarded as abandoned experiments?

Objected to as irrelevant and immaterial, as drawing conclusions of law which may be well enough to present to the court, but which this witness can hardly be presumed to have a knowledge of, and, therefore, cannot testify in regard to; and the question also specifically objected to as submitting to this witness whether the Holley report was a publication or not.

A. It is true that during the period mentioned by you, the difficulties of direct-metal process were recognized and discussed, and it is also true that some of them exist today. During that period attempts were constantly made to overcome such difficulties, both by more careful blast-furnace practice and mechanical means of handling the molten metal, particularly by mixing the metal from several furnaces in one ladle. And I do not think that so handling the metal, I mean now in a movable ladle which goes direct from the blast furnaces to the converters, can be considered as having been abandoned, as there are works running on direct metal which do not use anything approaching the Jones design.

X Q. 119. Please state whether an open-hearth furnace is not in fact a reverberatory furnace?

A. It is.

X Q. 120. Is it not a fact that when molten metal is subjected to treatment in an open-hearth furnace, or generally in a reverberatory furnace, the effect is to reduce the amount of silicon and to that extent to impair the utility of the molten metal for treatment in the Bessemer converter?

A. I do not understand what you mean by "treatment" in your question; if you mean the mere fact of keeping it molten, I would not regard that as properly designated by the word "treatment." The effect upon metal so held in a furnace would depend upon the conditions of the flame in that furnace and the admission or
476 exclusion of air in that furnace. It is true that large masses of metal held molten for any length of time will lose silicon to a small percentage, and it is also true that for the successful treatment of metal in the Bessemer converter, there is not as high a percentage of silicon required in direct metal as in remelted or cupola metal.

X Q. 121. When I spoke of treatment in the last question, do you not understand me as meaning the treatment of the molten metal by application of flame to its surface?

A. May I ask if you mean simply enough flame to hold it molten, or for a further effect upon the metal?

X Q. 122. I mean such application of flame to the surface of molten metal as occurs in an open-hearth or in a reverberatory furnace.

A. There is always a fixed purpose to produce a desiliconizing effect where metal is treated in a reverberatory or open-hearth furnace. The amount and rapidity of such action depending upon the

lining of the furnace. I mean by that the lining of the hearth of the furnace and the character of the flame admitted into the furnace. But it is perfectly possible and practical to simply hold the metal liquid without carrying the desiliconization to any great extent.

X Q. 123. How little silicon could you remove from molten metal in a reverberatory furnace during the exposure of such metal in such furnace, *say for a period of ten hours?*

A. I should think it would be difficult to hold one mass of molten metal that length of time without considerable desiliconization; I cannot now give you exact figures. When I say one mass of metal, I mean the same metal without additions to or substractions from it.

X Q. 124. Will you please now state what you find in the Witherow patent 327,425, which particularly describes the invention of the patent in suit, and points out the various steps of the process described in said Jones patent?

477 A. Mr. Witherow points out the desirability of using direct metal, also the desirability of separating the tapping of a blast furnace from the charging of a converter, and provides an intermediate receptacle which is covered and provided with means for artificial heating to render such practice practicable, and in so doing, to my mind, he enumerates the points of the Jones patent, and in fact I know that he so told Capt. Jones.

Complainant's counsel objects to the witness replying to the question without any regard to its terms or purpose, and padding the record with utterly irrelevant matter as to which he was not interrogated. The witness is requested to confine his answer to pointing out those parts of the specification of the Witherow patent which fully describe and set forth the invention of the patent in suit.

Defendant's counsel notes on the record that the complainant's counsel broke into the answer of the witness, and when defendant's counsel requested that the witness be permitted to proceed with his answer, complainant's counsel refused to permit him to do so, and defendant's counsel then told the witness to proceed with his answer, which complainant's counsel would not permit him to do, but insisted upon entering the above objection. Defendant's counsel now instructs the witness that he is entitled to finish his answer, and that the portion which was entered on the record will be read to him if he so desires.

Complainant's counsel notifies defendant's counsel that by instructing the witness to proceed with utterly irrelevant matter, he imperils the use of the entire deposition, and if he chooses to persist in so doing, he must take the consequences.

Defendant's counsel replies that he does not know what the witness intended to answer, though complainant's counsel seems to anticipate some testimony which would be injurious to the

478 complainant; he protests, however, against such attempts to intimidate the witness, and to take from him the right to answer a question as he sees fit.

Witness continues his answer: It happened that at the time of——

The witness is again requested to confine his answer to the question.

Witness continues: I cannot see why what I am going to say will be as irrelevant to the questions as you seem to think, and, therefore, will continue my answer. It happened that at that time of the application for the Witherow patent I was acting as consulting engineer for him, and, therefore, am specially familiar with what he was seeking to protect by his patent.

X Q. 125. In the specification of the Witherow patent, it is stated in lines 52 to 54 of the first page in the printed patent that the receptacle *b* is designed to hold the entire cast of the furnace *a*, being of sufficient size for that purpose. Is not this receptacle *b* what you have called the ladle?

A. Yes, sir.

X Q. 126. The object of the Witherow patent, as it appears to me, and I want you to say whether I am correct or not, is to provide a receptacle into which the entire contents of a blast-furnace charge may be run so as to keep it in a sufficiently heated and melted condition to transfer it by means of a ladle to the Bessemer converter, the idea being that the receptacle shall be of sufficient size to contain the whole charge of the blast furnace, so that the blast furnace may be emptied whether the converter or converters are ready to receive their charge or not, and that from this receptacle the molten metal is tapped from time to time until it is all emptied ready to receive another blast-furnace charge, am I not correct?

A. You are correct, as I understand it, so far as the provision of an intermediate receptacle for the molten metal between the
479 blast furnace and the converters, thus rendering the operation of the one independent of the other, but I do not understand that Mr. Witherow made it necessary in his patent that the receiving receptacle should be entirely emptied before other metal was tapped into it from the blast furnace.

X Q. 127. Where do you find in this specification the statement that the receptacle *b* is to be only partially emptied before another blast-furnace charge is introduced?

A. I do not find it so stated, neither do I find it stated that it shall be entirely emptied. My knowledge of the art would keep me from thinking that such was the intention of the inventor; I mean by that that it should be entirely emptied.

X Q. 128. If the receptacle *b*, which is made to receive the entire cast of the blast furnace, be not emptied before another blast-furnace charge is introduced, and this process of only partial withdrawing of the molten metal before another blast-furnace charge was introduced, and so on successively, as you seem to imagine, how would the accumulated slag and kisch be get rid of?

A. He provides tapping holes for the slag, which he designates as *h*, and you will observe that he places them at different heights,

evidently expecting the operation to be performed when the receptacles contained different amounts of metal.

X Q. 129. In the use of a mixer by successive introductions of molten metal and withdrawals of a part thereof from time to time, is it not a fact that the slag which otherwise would remain fluid and could be withdrawn each time the receptacle was emptied would become a solid crust and be incapable of removal in the manner you have mentioned?

A. Understanding you to refer to the Witherow patent, Mr. Witherow depended on keeping this slag fluid by the heat which he proposed to develop in his receptacle. I am not giving my opinion as to whether or no I consider Mr. Witherow's device a good one.

480 X Q. 130. In reference to your answer to Q. 9, in relation to the practice of the Cambria Iron Co., I understand that you refer to what is known as cupola practice, do you not?

A. Yes, sir.

X Q. 131. Will you please state in what way the metal is selected for the cupola charge, so as to produce an output as uniform as possible as to the character and chemical constitution of the metal?

A. There was a regular proportioned mixture of different kinds of pig iron and iron and steel scrap charged into the several cupolas, the metal result being accumulated in a common receiving ladle. I mean by that the same ladle for the several cupolas.

X Q. 132. In this case the selection of metal was what we may call a cold selection, that is to say, the metal selected for the cupola was pig metal from the blast furnace which had become cold, which was then selected to be remelted in the cupola; is not that so?

A. It was.

X Q. 133. In the direct Bessemer process where the metal is carried from the blast furnaces either directly or through the medium of a mixer, this practice which I have denominated cold selection is not practicable, is it?

A. It is not, and such fact led to the development of quick chemical processes, so that some knowledge could be quickly obtained of the chemical character of the metal.

X Q. 134. In cupola practice where the metal if carefully selected from pigs of iron, the quality and constituents of which are readily ascertained by test before being charged into the cupola, the quality of the metal produced or the cupola run is ordinarily such as to be fit for converter charge, is it not?

A. It is.

X Q. 135. In the direct process, on the contrary, the pro-
481 duct of the various blast furnaces is not of such regular quality and uniformity as that their output is fit for charging into the Bessemer converter?

A. If the blast furnaces are properly handled, it is, as has been evidenced by the hundreds of thousands of tons of good steel which has been made from such metal. The intelligent blast-furnace manager is not ignorant of the quality of metal which he is pro-

ducing; it is true that there is greater variation liable to occur than in cupola-metal practice, but not fatally so.

X Q. 136. If this be so and if the product of the blast furnace runs with such regularity as to quality and chemical constituents that their product is fit without further treatment for introduction into the converters, whence arises the great utility of mixing the charge from various blast furnaces of which we hear so much in various patents and the literature of the art?

A. For exactly the same reasons that the accumulating ladle was of value in the cupola practice.

X Q. 137. Have you in your own experience ever worked with the direct process?

A. Yes, sir. My very first experience in the Bessemer process in 1865 and 1866 was with direct metal from charcoal blast furnace at Wyandotte, Mich.

X Q. 138. Was not this an experimental use to which you have referred?

A. The plant was an experimental plant so far as the making of Bessemer steel from American materials was concerned, but so far from the use of direct metal being considered experimental, I would say that the works were originally constructed to take that kind of metal alone; later, a change of management resulted in the introduction of the practice of melting pig in a reverberatory furnace, and later again that furnace was replaced by a cupola, but the direct arrangement was always retained and used from time to time during some nine months that I was in charge of the works—from July, 1865, to the first of May, 1866.

482 X Q. 139. Please to describe the location of the scales for weighing the metal accumulated in what you have called the Holley receiving ladle?

A. I would ask if you mean the receiving ladle introduced in the cupola practice.

Counsel for complainant replies that he does.

At Cambria and Troy, I specify these works, as I have referred to them as having been under my charge, there were two ladles provided, each swung on trunnions and standing on separate scales in a central location to the several cupolas, the troughs or gutters from which were so arranged that the metal could run into either of the ladles. These ladles were also at such an elevation that the metal from them when being poured was run by drawing into either one of the two converters which it was desired to use.

X Q. 140. Then the ladle was not removed from the scale excepting for repairs, was it?

A. As a rule, it was never taken from the scales. Of course if the iron from which the ladles were formed needed repairing, they might be, but not for repairing the lining of the ladles.

X Q. 141. What is a smelting furnace?

A. Any furnace in which material is melted.

X. Q. 142. Then a cupola or an open-hearth furnace, or either of them is a smelting furnace under your definition.

A. I should say so.

X Q. 143. Is not a blast furnace the only sort named by Jones in the patent in suit for obtaining molten metal?

A. I think it is.

X Q. 144. Does not Jones in the patent in suit state that in the use of his invention he employs metal in a number of parts taken from different smelting furnaces, or from the same furnace at different casts?

A. I should say that he does not limit himself to the metal
483 taken at one time, but says that it may be of a number of parts taken from different smelting furnaces, or from the same furnace at different casts, or at different periods of the same cast.

X Q. 145. Is it not a fact that Jones, in the patent in suit, spoke of and refers to the treatment of blast-furnace metal?

A. It is.

X Q. 146. In the patent in suit, where Jones speaks about using variety of forms of apparatus and specifies for example, receiving the metal into a charging ladle, does he not specify as charging a number of small portions of metal taken from several ladles or receiving vessels containing crude metal obtained at different times or from different furnaces, the mixing being performed by the act of pouring the metal into the charging vessel?

A. He says further, "and other like means may be employed," and again he provides for mixing the metal by stirring it.

X Q. 147. The point of my inquiry is this, when Jones speaks of mixing the metal in a charging ladle, he specifies the charging into the ladle of small portions of metal derived from different sources, is not this so?

A. Yes, it is.

X Q. 148. You have spoken of Holley's intermediate ladle; is not that ladle the same thing as what is ordinarily called a charging ladle?

A. I have never heard it spoken of in other terms than as a cupola ladle in cupola practice, that is the shop name for it.

X Q. 149. Then why have you, in your testimony, spoken of it as the receiving ladle?

A. Because that is what it is, and I find in reference to my article entitled "History of the Bessemer manufacture in America," read before the American Institute of Mining Engineers in 1876, that I then designated it as an "intermediate or accumulating ladle,"
484 and in giving my testimony I have been more particular and minute in description than would prevail in ordinary shop language.

X Q. 150. What is the meaning of the term "crude metal"?

A. Untreated cast iron.

X Q. 151. In both of the claims of the patent in suit the process particularly described is spoken of as a preliminary step to further refining treatment of the iron which in this particular instance is the Bessemer process; am I not right?

A. I think you are.

Objected to as unwarranted by the language of the patent.

X Q. 152. In your answer to Q. 37, have you taken into consideration the use in the second claim of the patent in suit of the word "successively" and the term "successively replenishing the receptacle with fresh ununiform additions"?

A. I think so, but you will please remember that I do not profess to be a patent lawyer and therefore not qualified to make nice distinctions which perhaps belong to the profession.

X Q. 153. Do you know what is the present condition of the "Terre Noire" works?

Objected to as immaterial and irrelevant.

A. I do not.

X Q. 154. How much of what you have stated in your answer to Q. 35 is of your own knowledge and how much is inference?

A. All of my answers relating to foreign works is based upon information obtained from reading and other sources than personal observation, as I have never been abroad.

Redirect examination by counsel for defendants:

R. D. Q. 155. In answering Q. 151 had you in mind the
485 statement in the Jones patent as follows: "My invention is not limited to its use in connection with converters, since similar advantages may be obtained by casting the metal from the mixing vessel into pigs for use in converters, puddling furnaces, or for any other uses to which pig iron may be put in the art"?

Counsel for complainant objects to the question for the reason that in his question which the witness answered, he did not specify the Bessemer converter process as the only refining process to which the invention might be applied, but as being the one mentioned in the patent, and further, that the claims, both of them, specifically refer to the process of the patent as being preliminary to a further refining process and that it is the claims which must govern in the interpretation of the scope of the patent and the invention covered thereby.

A. In answering the question my attention was directed simply to the 1st and 2d claim and I did lose sight of the preceding statements of the patent.

R. D. Q. 156. In answer 112, what do you mean by saying of the Snelus description "mechanically it certainly is not a full description"?

A. I mean that it does not describe the mechanism of the Jones receiver. The question being asked me as a mechanical engineer.

R. D. Q. 157. Am I correct in understanding that your answer 130 as to selecting and mixing pig metal in cupola practice had reference only to the practice at Cambria?

Objected to as leading.

A. I understood it as referring to my Cambria practice, taking the question in connection with the preceding one.

R. D. Q. 158. Do you understand that it was the practice in works operating on a large scale to generally select and mix iron in the cupola practice, as was done at Cambria?

486 A. So far as my observation has gone, it has been the general practice. Some concerns have not done it, but it has been the general practice.

R. D. Q. 159. Referring to the metal made at Wyandotte by the direct process, was it sold in the market?

A. It was. The Bessemer works were connected with an extensive rolling-mill plant owned by Capt. E. B. Ward, who was also largely interested in the Bessemer works, and the last month of my stay there, became their sole owner. He also was largely interested in rolling mills at Chicago and Milwaukee, and in those several works the steel made at Wyandotte was put into a variety of commercial products, such as rails, boiler plate, merchant bar sizes, etc.

R. D. Q. 160. You were asked in Q. 111 as to the practice at the Bethlehem works; do you know whether or not at those works, it was the custom to mix molten furnace metal and molten cupola metal, or not?

Objected to as leading and as not proper redirect.

A. I cannot answer from my personal knowledge.

R. D. Q. 161. You have referred to ladles which were permanently mounted on scales. Do you know of any instance in which the charging ladle was movable, being applied to and removed from the scales in the course of operation?

A. Yes, sir. I stated in my answer, if I recall it correctly, that I was describing the early Cambria and Troy days. When I last remodeled the works at Troy in 1885, I so arranged to use the ladle, it being pushed by a locomotive directly back of the converter and poured directly into it, the converters having been altered so as to turn over into the proper position to so receive the metal, and in doing this, I practically copied Capt. Jones' practice at the Edgar Thomson. At Bethlehem the ladle also was movable, which I have already described.

R. D. Q. 162. In answer to question 99, you state that if

487 the receiver was run well up to its total capacity, the slag, etc., could be pulled over the top of its sides. Please state whether that was a known practice in connection with molten metal at or prior to 1875?

A. It was the constant practice with the Holley accumulating cupola ladles, in fact slag was made on the top of the iron from the custom of keeping sprinkled, sometimes fine charcoal or more generally fine coke, over the top of the molten iron for the purpose of retaining its heat. This, together with the slag which would run into the ladle along with the iron from the cupolas, formed considerable slag, and it was the constant practice to pry it by a bar, over the side of the ladle. This was simply a continuation on a larger scale of the ordinary foundry practice and was customary from the earliest days of American Bessemer practice and hence on or before 1873.

R. D. Q. 163. Are you acquainted with the practice followed in removing slag or kish from receivers for holding direct metal, where you have seen such receivers in operation?

A. I can't say that I have ever seen such receivers so cleaned.

R. D. Q. 164. Referring to the Deighton patent, have you used the knowledge which you had in 1873, when it was granted, or knowledge subsequently obtained when you have interpreted the patent in connection with your direct and cross examination?

A. I have tried to carry my mind back to 1873; it is a pretty difficult problem to analyze the workings of one's mind.

Recross-examination:

R. X Q. 165. Were not the works at Wyandotte to which you refer, same as those mentioned by Mr. W. S. Durfee in his testimony in this case? I hand you herewith Mr. Durfee's testimony and refer you to the answer to the 2nd interrogatory?

A. They are undoubtedly the same works.

488 R. X Q. 166. At the remodeled works at Troy which you have mentioned, what was the location of the scales?

A. There was a scale immediately behind each converter.

ROBERT W. HUNT.

Adjourned to meet Wednesday, Dec. 30th, at same place.

Met pursuant to adjournment.

Present: Counsel as before.

Testimony of Charles S. Price.

CHARLES S. PRICE, a witness on behalf of defendants, being first duly sworn, deposes and says in answer to interrogatories proposed to him as follows, to wit:

Q. 1. What is your name, age, residence and occupation?

A. Charles S. Price; 44; Johnstown, Pa.; manager Cambria iron works at Johnstown.

Q. 2. How long have you been connected with the Cambria iron works?

A. Twenty and one-half years.

Q. 3. In what capacity were you employed at Cambria subsequent to 1879?

A. From 1876 to 1879 I was draftsman; '79 to '81, foreman of open-hearth department; '81 to '84, superintendent of open hearth; '84 to '91, superintendent of Bessemer steel department; since then general manager.

Q. 4. Have you knowledge of the manufacture of Bessemer steel at Cambria from cupola metal during your service?

A. I have.

Q. 5. It appears in evidence that at one time it was the practice at Cambria to select the pig irons with reference to quality for charging the cupolas. Please state whether this practice was continued, and if not, when it was discontinued.

489 A. In July, 1881, it was discontinued.

Q. 6. After July, 1881, what was the practice at Cambria as to charging the cupolas with pig metal?

A. The pig metal as received from the blast furnaces was dumped promiscuously into the stock bins according as there was room vacant, and from that charged promiscuously into the cupolas. That practice has since been continued.

Q. 7. Previous to 1888, what was the practice at Cambria as to handling the molten metal between the cupolas and the converters?

A. By means of a receiving ladle. That ladle was filled with metal, tapped from the several cupolas in operation, weighed and then the proper amount for a converter charge poured out.

Q. 8. What was the capacity of the Cambria ladle, and what the usual charge for the converter?

A. The ladle capacity from 1871 to 1879 was 21,000 pounds; the converter charge was 12,500 pounds; from 1879 to 1888 the ladle charge was 28,000, the converter charge was 15,500 pounds; it was changed then in 1889 to 32,000 ladle capacity, converter capacity was 26,000.

Q. 9. What was the average amount tapped from each cupola into the ladle?

A. From 4,000 to 6,000 pounds varying with circumstances.

Q. 10. How many cupolas were employed at Cambria?

A. Six; five usually in operation.

Q. 11. Am I correct in understanding your testimony to mean that this Cambria ladle holding at one time 21,000 pounds, enlarged later to 28,000 pounds, and again enlarged to 32,000 pounds capacity, was filled with molten metal tapped in part from one cupola and in part from other cupolas? And that from its accumulated mass, the proper amount for a converter charge was poured out?

A. Your understanding is correct.

490 Q. 12. Prior to 1888, what was the usual practice at Cambria as to emptying or leaving molten metal in the intermediate ladle when the converter charge was taken out?

A. It was the custom to leave in the ladle an amount of metal equal to the difference between the converter charge and the full-ladle capacity.

Q. 13. What was the practice as to refilling the ladle from the cupolas? Was it emptied or not before refilling?

A. It was not the custom to pour it out. The ladle was again filled to its full capacity by retapping the cupolas.

Q. 14. Am I to understand that you tapped more than one cupola into the vessel or ladle containing the molten metal which remained after the converter charge had been taken out?

Question objected to as leading.

A. Yes.

Q. 15. Say whether or not, as a matter of fact, there was a mixture in the intermediate ladle of the molten irons from the different cupolas.

A. There was.

Q. 16. Will you say whether there were any advantages attending this mixture, and if so, name some of them?

A. The metal from the several cupolas necessarily varied from time to time considerably, both in chemical and physical conditions; at times the metal being such from one or two of the cupolas that in themselves they would be unfit for converter use. But by the means which was afforded by the intermediate ladle, the metal from this one, or the two, cupolas, would be averaged with the better adapted metal for converting from the others.

Q. 17. How, or in what way, was the intermediate ladle at Cambria filled from the several cupolas?

A. It was tapped, and by means of short troughs run into the ladle. The ladle was stationary at that time under the trough leading from the cupola.

Q. 18. Are you familiar with reverberatory furnaces?

491 A. In general, yes.

Q. 19. Assume a coal-fired reverberatory furnace of from 50 to 60 tons capacity, and say whether it would be possible practically to receive in such furnace molten blast-furnace metal, either alone or mixed with molten cupola metal, and to retain such metal in the furnace in a molten state and in suitable condition for use in a Bessemer converter, for any considerable period of time.

A. It would be possible.

Q. 20. Assuming molten cast iron to be delivered into a furnace such as above stated, would there be any serious difficulty in retaining the molten metal and in condition for use in a Bessemer converter?

A. I do not consider there would be any serious difficulty, owing to the fact that the heat provided by the flame would maintain the bath at a sufficiently high temperature.

Cross-examination by counsel for complainants:

X Q. 21. Are you a stockholder of the Cambria Iron Co.?

A. A small one.

X Q. 22. How long have you been a stockholder?

A. About eleven months.

X Q. 23. In the answer filed by the Cambria Iron Co. in this suit they say: "It" (that is, the Cambria Iron Co.) "has employed, for many years prior to the grant of said letters patent" (referring to the patent in suit) "and since that time, ladles or receivers into which molten metal from two or more furnaces was introduced from time to time and from which the charge from the converter was drawn from time to time as required, it having been the practice of this defendant" (meaning the Cambria Iron Co.) "to employ such apparatus and to practice such way of making Bessemer steel for twenty-five years or more." State whether during your connection with the Bessemer department of the Cambria iron works

492 the practice has been continuously the same to the present time, and whether your testimony which you have just given as to the practice corresponds with the statement in that answer.

Objected to as incompetent; as improper in cross-examination.

A. The testimony as to the practice during my connection with the Bessemer department agrees with the statement quoted from the defendant's answer.

X Q. 24. Would you make the same answer as to the time during which you were general manager, namely, from the year 1891 to the present time?

Objected to as incompetent and not in the line of cross-examination.

A. I would, then.

X Q. 25. Have you, during all that time at the Cambria iron works, used the same kind of furnaces from which the molten metal was taken into receivers and thence charged to the converters, being drawn from the receivers from time to time as required? I refer to the time from 1881 to the present time.

Objection repeated.

A. From the time subsequent to 1881, up until November, 1895, the molten metal for converter use was drawn entirely from cupolas. Since that period the practice has been to use molten metal partly from cupolas and partly direct from blast furnaces.

X Q. 26. The portion which I read to you from the answer of the defendants seems to imply that the receiver into which the molten metal was poured and from which the molten metal was taken from time to time into converters, was during all that time at Cambria, the same kind of a receiver and used in the same way. If not, please state what the difference was at different times and when such changes were made.

Objection repeated.

493 A. So far as the specific receiver, as I understand to be mentioned in the answer is concerned, we are still using, no matter which source we draw our molten metal supply from.

X Q. 27. Then I am to understand from you, am I, that from 1881 to the present time, no other or different kind of receiver has been used for receiving the molten metal from the furnaces, whether cupolas or blast furnaces, or both, from which the molten metal was conveyed and charged into the converters than that which you call the "specific" receiver in your last answer?

A. No, sir; in using the molten metal from the blast furnaces we have introduced an intermediate storage reservoir or receiver, from which the specific receiver mentioned in my previous answer is filled or partially filled as circumstances of practice may render advisable.

X Q. 28. Then the intermediate storage reservoir or receiver referred to in your last answer is not the "specific" receiver which you mention in your answer to Q. 26?

A. No, sir.

X Q. 29. When I asked you in Q. 26 whether the receiver into which the molten metal was poured and from which the molten

metal was taken from time to time into converters was during all that time the same kind of a receiver, you understood my question to carry you down to Nov., 1895, and no further, did you?

A. No, sir; it carries down to date.

X Q. 30. Then when you have spoken of the receiver into which the molten metal was taken from time to time from the furnaces and then from time to time into converters, you do not mean me to understand that the same kind of a receiver was used for this purpose during the whole of that time?

Objection continued as to all matter since 1879.

A. I do, the same general character.

494 X Q. 31. Was not the intermediate storage reservoir or receiver referred to in your answer to Q. 27 used in addition to the ladle which you have spoken of as being used in your examination-in-chief?

A. It was used in addition to that for that portion of the molten metal taken from the blast furnaces direct.

X Q. 32. And when you used this storage reservoir or receiver for receiving the blast-furnace metal, did you also use the ladle of which you have spoken in your examination-in-chief?

Same objection.

A. We did.

X Q. 33. After the storage reservoir was introduced, were there any changes made as to the quantity of metal poured into the ladle from what had been the practice prior to the introduction of the storage reservoir?

A. As there was no change in the apparatus, it being used to receive equally from the cupolas or from the receiving vessel, as might be desired, there was no change of practice relative to this ladle, or receiver.

X Q. 34. In your testimony-in-chief, I understand you to say that prior to 1879 the ladle capacity was 21,000 pounds, while the converter charge was only 12,500; that from 1879 to 1889 the ladle capacity was 28,000 and the converter charge 15,500; do you know why the change was made in the relative amount of ladle capacity and converter charge?

A. In general, it was owing to the desire to obtain a larger receptacle in order to hold or store a larger body of metal between the cupolas and the converters.

X Q. 35. How frequently were those ladles filled and emptied, partially or wholly?

A. As frequently as the converters were ready to receive a charge. This varied according to the time required to blow a heat in addition to whatever intervals were caused by delay.

495 X Q. 36. Exclusive of accidental delays, did this interval in the use of the ladle mean days, hours or minutes, usually?

A. Varying from minutes to several hours. Usually about fifteen minutes.

X Q. 37. Why, then, in your answer to the 34th Q. in speaking of

the cause of the filling of the ladle so as to hold more than a single converter charge, did you use the term "storing" in regard to the metal left in that ladle?

A. Because we desired to obtain in general as large a body of metal as possible between the cupolas and the converters in order to not only equalize the supply but to render the two appliances, the cupola and converter, as far as possible independent of each other as to delays.

X Q. 38. In case of a delay involving, say several hours, after the pouring from the ladle a converter charge, what would become of the thirteen thousand pounds of metal still left in the ladle?

A. If the delay were such as to render it impossible to pour any of it into an empty converter the metal would have to be held in the ladle and the blast taken off the cupolas. Prior, as a rule, to such a contingency occurring, as a rule there was one empty converter. The metal poured into this converter, the blast taken off the cupolas by which means the larger capacity of ladle gave us that much more opportunity to drain the metal which continued to melt during such delay. The smaller the ladle, or in other words, the less in storage capacity, the more quickly we would be compelled to leave the metal stored back in the cupolas.

X Q. 39. How long could the remnant of metal after the charging of the converter be left in the ladle without solidifying?

A. Depending on its character, from an hour to two or three hours.

X Q. 40. When you used the ladle with the converters be-
496 fore you introduced the mixing reservoir for mixing the metal from the blast furnaces, why was it that you left a larger percentage in the ladle after charging the converter than you did after 1889 when you used the mixing reservoir, the percentage prior to 1889 of metal left in the ladle being 48 per cent. and after 1889 less than 19 per cent.?

A. We did not use the large intermediate reservoir until November, 1895, so that from 1889 the time of the change in the relative proportions between the converter charge and the ladle capacity were the same as they are now. The change was, therefore, long prior to the adoption of the large intermediate reservoir, and had no connection with it.

X Q. 41. What was the capacity of the mixing reservoir which you began to use in the fall of 1895?

Objection continued to this line of examination.

A. The capacity of the large intermediate reservoir for receiving the direct molten metal from the blast furnaces was 300 tons.

Redirect examination without waiver of objection:

R. D. Q. 42. Please say whether or not the rate of consumption of metal by the Cambria converters continued unchanged from 1879 downward?

Objected to as not proper redirect.

A. It increased steadily from year to year.

R. D. Q. 43. You have referred to the fact that since the introduction of the large reservoir, part of the molten metal was used from the blast furnace and part from the cupolas. Please say into what these respective metals were tapped and how they were used.

A. Into the same intermediate receiving ladle which had been used when using cupola metal alone.

R. D. Q. 44. Into what was the metal tapped from the blast furnaces and from the cupolas?

A. The blast-furnace metal is tapped into a ladle and transported to the Bessemer steel plant, and there poured into the large
497 reservoir; from there the metal is poured into the same intermediate ladle as is used for the cupola practice.

R. D. Q. 45. Referring to Q. 38, was it necessary under ordinary working conditions at Cambria to retain in the ladle the remaining metal for a period of several hours?

A. Such occur-ence was exceedingly exceptional and due only to an unusual accident.

R. D. Q. 46. You have referred to the use of the large storage vessel adopted in 1895. Please say whether or not it was practical to deliver all blast furnace metal to this vessel without selection?

A. No, sir. We reject the extremes in silicon as unfit to go through the reservoir, consequently they are cast on the pig bed at the furnaces.

R. D. Q. 47. Then, if I understand you correctly, the use of the large reservoir, or mixer, or whatever it may be called, does not permit you to use all the blast-furnace metal or blast-furnace metal indiscriminately for the making of Bessemer steel?

The question is objected to as containing a statement which the witness is expected to assent to, and is therefore clearly leading.

A. No, sir.

Recross-examination:

R. X Q. 48. You have in your redirect examination made some statements in regard to the practice with the use of the large storage reservoir at the Cambria works. Now, to avoid any possible misunderstanding of your meaning as to what actually takes place at the Cambria works, I would like you to tell me if the following is not a correct statement: Molten pig metal is tapped from the several blast furnaces from time to time and is received into a ladle and from thence is poured into the large mixing reservoir as received from the blast furnaces, and from this reservoir molten
498 metal is poured from time to time by the tipping of the reservoir into what you have called an intermediate ladle whenever needful to charge the converters, and the molten metal conveyed by the ladle into the converters, and so on successively from time to time; is not this a correct statement?

A. That describes the process so far as relates to molten metal direct from the blast furnaces. If it were put into the vessels without admixture of cupola metal, our usual practice is, however, to

mix this metal from the large storage reservoir with metal from the cupola by running the intermediate ladle to the cupolas first and then to the converter.

C. S. PRICE.

Adjourned to meet Dec. 31st, 1896.

Met pursuant to adjournment.
Present, counsel as before.

George E. Thackray.

GEORGE E. THACKRAY, a witness called on behalf of defendants, being interrogated by Mr. Dodge, deposes and says as follows, to wit:

Q. 1. State your name, age, residence and occupation.

A. George E. Thackray; 40 years; Johnstown, Pa.; civil engineer, now employed as assistant engineer for the Cambria Iron Co. at Johnstown.

Q. 2. How long have you been employed as assistant engineer by the Cambria Iron Co.?

A. Almost seven years, or since March, 1890.

Q. 3 While in the service of the Cambria Iron Co., have you had occasion to take charge of any stationary apparatus for receiving and mixing molten metal from the blast furnaces for use in Bessemer converters?

A. Yes.

499 Q. 4. Please describe that stationary receiving and mixing apparatus; tell how it was operated and give the results obtained.

A. At the request of Joseph Morgan, chief engineer, I conducted a test of the operation of a fixed receiver at the Bessemer steel works of the Cambria Iron Co. The receiver was a brick-lined vessel about nine feet in diameter inside of the lining, and about six and one-half feet deep from its bottom to the bottom of the pouring-in spout. It was provided with a spout near its top by means of which blast-furnace metal could be charged into it, and it was provided with tapping holes near the bottom through which the iron could be withdrawn. Its nominal capacity was about 140,000 pounds. A portion of the brick-work at the top of the vessel was cut away, leaving an opening about three feet long and three or four courses high. The operation began on Tuesday, July 28, 1896, at 6 p. m., and continued without interruption until Saturday noon, August 1, at which time the week's work of the Bessemer steel works was finished. During the operation, blast-furnace metal from five blast furnaces was delivered to the receiver by means of ladles mounted on cars, these ladles holding when full, about 40,000 pounds. The amounts delivered to the receiver were generally less than a ladle full. During the operation metal was withdrawn from the receiver through one of the tapping holes, being drawn into the accumulating or receiving ladle of the Bessemer plant, from which it was delivered to the Bessemer converters

and manufactured into steel in the usual manner. At times a full Bessemer heat of 28,000 pounds was withdrawn from the receiver, but generally a less amount was taken. During the operation a record was kept of the amounts of metal put into, withdrawn from, and remaining in the receiver. The amounts put in were determined by weighing the ladles on the regular track scales adjoining the Bessemer steel works. The amounts in the receiver at
500 different times were determined by measurement of the height of metal in the receiver, knowing which and the quantities introduced, the amounts withdrawn were figured. During the operation, samples were taken in duplicate from each portion of metal put into and withdrawn from the receiver.

Q. 5. Can you produce the drawing of the fixed receiver described in your last answer?

A. This is a drawing of the fixed receiver which was operated as described.

The drawing referred to by the witness is offered in evidence and marked "Defendant's Exhibit Fixed Receiver."

(Here follows diagram marked p. 500*a*.)

Q. 6. Can you produce the record of operation with the fixed receiver referred to in your last answer?

A. These three sheets contain this record in tabular form.

Q. 7. Please state, referring to the report just mentioned, what the figures in the several columns represent.

A. The figures in column 1 give the dates of the operation; those in column 2 are the sample or test numbers; column 3 gives the time in hours and minutes of the various steps of the operation; column 4 shows the percentage of silicon in the various portions of the blast-furnace metal which were delivered to the receiver by means of the ladle; column 5 shows the percentage of silicon in the various portions of metal withdrawn from the receiver; column 7 shows the quantities of blast-furnace metal charged into the receiver at the time stated; column 8 shows the quantity of metal withdrawn from the receiver through the tapping hole at the times stated; and column 9 shows the quantity of metal remaining in the receiver at the times stated after pouring blast-furnace metal into the receiver or tapping metal therefrom.

Q. 8. You have not referred to column No. 6 of the report. Please state what it represents.

A. Column No. 6 is headed "Theoretical Sil. %." This is the theoretical percentage of silicon in the metal in the receiver
501 at the times stated, based upon the amounts of metal put in, withdrawn and remaining in the receiver, and is figured mathematically by proper combination of these figures taken in connection with the percentage of silicon in the various portions introduced into the receiver. It is that content of silicon in the receiver metal which would be obtained providing that the portions added became thoroughly intermingled with those already in the

United States Circuit Court
Western District of Pennsylvania
Carnegie Steel Co. Limited
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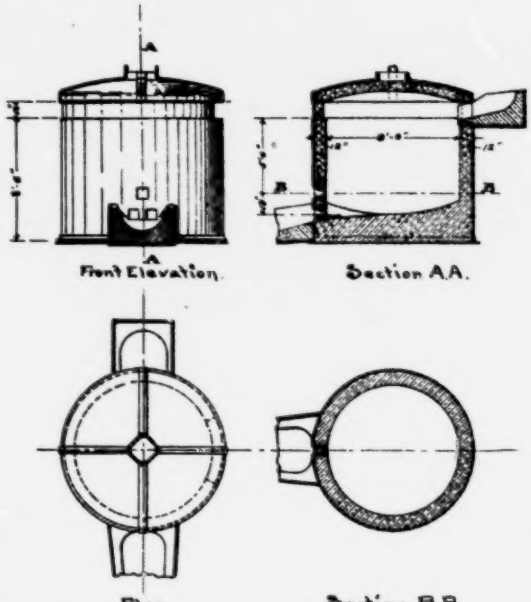
Defendants Exhibit
Fixed Receiver
Robert C. Totten
Examiner

EXPERIMENTAL MIXER.
AS USED AT
BESSEMER STEEL WORKS.
Cambria Iron Company. Johnstown Pa
July 28 to Aug. 1. 1896.
Scale 1" = 1 ft.



Front Elevation. Section A.A.

Plan. Section B.B.

Carnegie Steel Co.
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Cambria Iron Co. } p. 500a

United States Circuit Court
Western District of Pennsylvania.
Carnegie Steel Co. Limited
vs
Cambria Iron Co.

Defendants Exhibit -
Tabular Record, Fixed Mixer
Sheet 1.
Robt. C. Taft
Examiner

1	2	3	4	5	6	7	8	9
Date 1896	Test No.	Time	Sil. in Ladle %	Sil. in Receiver %	Theoretical Sil. %	Amt. Put In Lbs.	Amt. Taken Out Lbs.	Amt. in Mixer After Pouring & Tap Lbs.
7/28	1-L	6:05 P.M.	1.29	----	----	40000	-----	40000
"	2-L	6:35 "	.66	----	.99	36000	-----	76000
"	3-L	6:56 "	.68	----	.89	37000	-----	113000
"	1-R	7:28 "	----	.96	----	-----	23000	90000
"	2-R	7:40 "	----	.93	----	-----	23000	67000
"	4-L	8:23 "	.92	----	.90	36000	-----	103000
"	3-R	8:33 "	----	.93	----	-----	23000	80000
"	4-R	10:19 "	----	.91	----	-----	23000	57000
"	5-L	10:27 "	1.56	----	1.16	37000	-----	94000
"	5-R	10:35 "	----	1.09	----	-----	15000	79000
"	6-R	11.01 "	----	1.11	----	-----	15000	64000
"	6-L	11:08 "	.92	----	1.07	37000	-----	101000
7/29	7-R	12:34 A.M.	----	1.10	----	-----	20000	81000
"	8-R	12:51 "	----	1.09	----	-----	20000	61000
"	7-L	12:58 "	.90	----	1.01	37000	-----	98000
"	9-R	1:40 "	----	1.03	----	-----	15000	83000
"	10-R	1:58 "	----	1.12	----	-----	15000	68000
"	8-L	2:04 "	.96	----	.99	37000	-----	105000
"	11-R	2:28 "	----	1.01	----	-----	20000	85000
"	9-L	2:35 "	1.69	----	1.21	38000	-----	123000
"	12-R	4:18 "	----	1.25	----	-----	23000	100000
"	13-R	4:36 "	----	1.26	----	-----	23000	77000
"	10-L	4:40 "	1.11	----	1.17	38000	-----	115000
"	14-R	4:56 "	----	1.28	----	-----	15000	100000
"	15-R	5:20 "	----	1.23	----	-----	23000	77000
"	11-L	5:26 "	.89	----	1.08	37000	-----	114000
"	16-R	5:47 "	----	1.10	----	-----	23000	91000
"	17-R	6:25 "	----	1.13	----	-----	23000	68000
"	12-L	6:34 "	2.19	----	1.42	30000	-----	98000
"	18-R	7:12 "	----	1.11	----	-----	23000	75000
"	19-R	7:28 "	----	1.45	----	-----	23000	52000
"	13-L	9:54 "	1.03	----	1.27	32000	-----	84000
"	20-R	10:05 "	----	1.30	----	-----	23000	61000
"	21-R	10:29 "	----	1.32	----	-----	15000	46000
"	14-L	10:38 "	2.79	----	1.87	30000	-----	76000
"	22-R	10:55 "	----	2.23	----	-----	27000	49000
"	15-L	11:07 "	2.51	----	2.00	12000	-----	61000
"	23-R	11:52 "	----	2.17	----	-----	30000	31000
"	16-L	12:14 P.M.	2.15	----	2.08	30000	-----	61000
"	24-R	12:40 "	----	2.15	----	-----	13000	48000
"	17-L	12:55 "	.68	----	1.48	36000	-----	84000
"	25-R	1:17 "	----	1.28	----	-----	30000	54000
"	18-L	1:28 "	.67	----	1.17	33000	-----	87000
"	26-R	1:45 "	----	.99	----	-----	23000	64000
"	27-R	2:34 "	----	1.09	----	-----	15000	49000
"	19-L	2:51 "	.74	----	1.00	33000	-----	82000
"	28-R	3:50 "	----	.98	----	-----	25000	57000
"	29-R	4:29 "	----	.99	----	-----	23000	34000
"	20-L	5:00 "	2.38	----	1.64	30000	-----	64000
"	21-L	5:21 "	2.00	----	1.73	22000	-----	86000
"	30-R	5:35 "	----	1.85	----	-----	20000	66000
"	22-L	5:45 "	.59	----	1.33	36000	-----	102000
"	31-R	7:20 "	----	1.18	----	-----	20000	82000
"	32-R	7:40 "	----	1.14	----	-----	18000	64000
"	23-L	7:47 "	1.45	----	1.37	31000	-----	95000
"	24-L	9:06 "	1.44	----	1.39	32000	-----	127000
"	33-R	9:25 "	----	1.33	----	-----	30000	97000
"	34-R	9:43 "	----	1.41	----	-----	23000	74000
"	25-L	9:50 "	.81	----	1.20	35000	-----	109000

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United States Circuit Court
Western District of Pennsylvania.
Carnegie Steel Co. Limited
vs
Cambria Iron Co.

Defendant's Exhibit - Tabular Record - Sheet 1
Fixed Mixer -
Robt. C. Totten
Examiner

1	2	3	4	5	6	7	8	9
Date 1896	Test. No.	Time	Sil. in Ladle %	Sil. in Receiver %	Theoretical Sil. %	Amt. Put in Lbs.	Amt. Taken Out Lbs.	Amt. in Mixer After Pouring Tap. lbs.
7/29	35-R	9:55 P.M.	----	1.39	----	-----	30000	79000
"	36-R	11:20 "	----	1.04	----	-----	23000	56000
"	26-L	11:32 "	1.34	----	1.26	36000	-----	92000
7/30	37-R	12:51 A.M.	----	1.17	----	-----	30000	62000
"	27-L	1:00 "	1.01	----	1.17	32000	-----	94000
"	38-R	1:33 "	----	1.12	----	-----	23000	71000
"	28-L	1.42 "	2.93	----	1.68	29000	-----	100000
"	39-R	2:56 "	----	1.35	----	-----	23000	77000
"	40-R	3:10 "	----	1.75	----	-----	12000	65000
"	29-L	3:17 "	1.29	----	1.56	31000	-----	96000
"	41-R	5:08 "	----	1.65	----	-----	28000	68000
"	30-L	5:20 "	2.64	----	1.87	28000	-----	96000
"	42-R	6:35 "	----	2:05	----	-----	32000	64000
"	31-L	6:46 "	1.05	----	1.60	32000	-----	96000
"	43-R	7:48 "	----	1.51	----	-----	23000	73000
"	32-L	9:03 "	1.69	----	1.62	28000	-----	101000
"	44-R	9:41 "	----	1.55	----	-----	34000	67000
"	33-L	9:53 "	1.13	----	1.46	32000	-----	99000
"	45-R	10:15 "	----	1.37	----	-----	34000	65000
"	34-L	10:27 "	1.56	----	1.50	30000	-----	95000
"	46-R	10:59 "	----	1.52	----	-----	34000	61000
"	35-L	11:10 "	2.15	----	1.74	37000	-----	98000
"	47-R	12:11 P.M.	----	1.86	----	-----	35000	63000
"	36-L	12:20 "	1.07	----	1.56	24000	-----	87000
"	37-L	2:02 "	.86	----	1.37	32000	-----	119000
"	48-R	2:26 "	----	1.25	----	-----	23000	96000
"	49-R	3:01 "	----	1.29	----	-----	23000	73000
"	38-L	3:16 "	1.83	----	1.45	16000	-----	89000
"	50-R	4:00 "	----	1.35	----	-----	10000	79000
"	39-L	4:57 "	1.27	----	1.40	30000	-----	109000
"	51-R	5:08 "	----	1.34	----	-----	20000	89000
"	40-L	5:44 "	1.55	----	1.44	27000	-----	116000
"	52-R	6:06 "	----	1.56	----	-----	23000	93000
"	41-L	6:12 "	1.77	----	1.49	17000	-----	110000
"	53-R	7:33 "	----	1.64	----	-----	30000	80000
"	42-L	7:46 "	1.43	----	1.47	28000	-----	108000
"	54-R	9:10 "	----	1.49	----	-----	30000	78000
"	43-L	9:16 "	1.93	----	1.58	24000	-----	102000
"	55-R	10:02 "	----	1.50	----	-----	30000	72000
"	44-L	10:11 "	1.64	----	1.59	14000	-----	86000
"	56-R	11:33 "	----	1.62	----	-----	15000	71000
"	45-L	11:45 "	1.41	----	1.53	34000	-----	105000
7/31	57-R	12:52 A.M.	----	1.64	----	-----	20000	85000
"	46-L	12:59 "	2.13	----	1.62	14000	-----	99000
"	58-R	1:44 "	----	1.68	----	-----	20000	79000
"	47-L	1:54 "	1.75	----	1.65	27000	-----	106000
"	59-R	3:38 "	----	1.80	----	-----	20000	86000
"	48-L	3:50 "	1.20	----	1.60	10000	-----	96000
"	60-R	5:17 "	----	1.60	----	-----	20000	76000
"	49-L	5:26 "	1.64	----	1.61	16000	-----	92000
"	61-R	6:58 "	----	1.68	----	-----	15000	77000
"	50-L	7:22 "	2.02	----	1.66	10000	-----	87000
"	62-R	7:55 "	----	1.64	----	-----	15000	72000
"	51-L	8:47 "	1.38	----	1.60	18000	-----	90000
"	63-R	8:54 "	----	1.53	----	-----	15000	75000
"	52-L	9:03 "	1.74	----	1.62	16000	-----	91000
"	64-R	9:33 "	----	1.65	----	-----	15000	76000
"	53-L	10:39 "	1.47	----	1.60	14000	-----	90000
"	54-L	11:04 "	1.22	----	1.54	17000	-----	107000

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Cambria Iron Co. }

United States Circuit Court
Western District of Pennsylvania

Carnegie Steel Co. Limited
vs
Cambria Iron Co.

Defendants Exhibit
Tabular Record, Fixed Mixer
Sheet 3.

Robt. C. Totten
Examiner.

1	2	3		4	5	6	7	8	9
Date 1896	Test No.	Time		Sil. in Ladle %	Sil. in Receiver %	Theoretical Sil. %	Amt. Put in Lbs.	Amt. Taken Out Lbs.	Amt. in Mixer After Pouring & Tap Lbs.
7/31	65-R	11:10	A.M.	----	1.45	----	----	20000	67000
"	55-L	11:32	"	1.04	----	1.47	13000	-----	100000
"	56-L	11:48	"	.75	----	1.39	13000	-----	113000
"	66-R	12:00	M.	----	1.43	----	-----	18000	95000
"	67-R	12:32	P.M.	----	1.33	----	-----	18000	77000
"	57-L	12:40	"	1.08	----	1.34	14000	-----	91000
"	58-L	12:53	"	.78	----	1.25	17000	-----	108000
"	68-R	1:10	"	----	1.21	----	-----	18000	90000
"	69-R	1:51	"	----	1.25	----	-----	18000	72000
"	59-L	2:11	"	2.76	----	1.45	11000	-----	83000
"	60-L	2:30	"	.76	----	1.34	17000	-----	100000
"	70-R	2:40	"	----	1.21	----	-----	20000	80000
"	71-R	3:17	"	----	1.32	----	-----	15000	65000
"	61-L	4:20	"	2.25	----	1.55	20000	-----	85000
"	62-L	4:44	"	1.28	----	1.60	17000	-----	102000
"	72-R	5:48	"	----	1.40	----	-----	20000	82000
"	63-L	5:56	"	2.82	----	1.71	15000	-----	97000
"	73-R	7:36	"	----	1.82	----	-----	20000	77000
"	64-L	7:45	"	2.68	----	1.87	15000	-----	92000
"	74-R	8:08	"	----	2.24	----	-----	20000	72000
"	65-L	8:15	"	2.12	----	1.93	27000	-----	99000
"	75-R	9:50	"	----	2.17	----	-----	20000	79000
"	66-L	9:58	"	3.03	----	2.07	11000	-----	90000
"	76-R	11:32	"	----	2.44	----	-----	20000	70000
"	67-L	11:41	"	2.28	----	2.13	27000	-----	97000
8/11	77-R	12:06	A.M.	----	2.29	----	-----	20000	77000
"	68-L	12:14	"	2.13	----	2.13	14000	-----	91000
"	78-R	2.22	"	----	2.39	----	-----	18000	73000
"	69-L	2:28	"	2.59	----	2.21	16000	-----	89000
"	79-R	3:48	"	----	2.37	---	-----	20000	69000
"	70-L	3:55	"	2.30	----	2.23	16000	-----	85000
"	80-R	5:07	"	----	2.27	----	-----	15000	70000
"	71-L	5:16	"	3.15	----	2.45	22000	-----	92000
"	81-R	6:36	"	----	2.48	----	-----	18000	74000
"	72-L	6:43	"	2.12	----	2.35	31000	-----	105000
"	82-R	7:31	"	----	2.27	----	-----	20000	85000
"	73-L	7:38	"	.92	----	2.17	12000	-----	97000
"	83-R	7:58	"	----	1.93	----	-----	25000	72000
"	84-R	8:46	"	----	1.90	----	-----	30000	42000
"	85-R	10:32	"	----	1.60	----	-----	15000	27000
"	86-R	11:32	"	----	2.06	----	-----	10000	17000

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Cambria Iron Co.
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receiver in such a way as to provide a homogeneous mixture, provided, of course, that the chemical work and the quantities are absolutely correct, and provided further that nothing is lost or changed in the operation. The theoretical silicons, therefore, as shown in column 6, as compared with the silicons actually obtained from metal withdrawn from the receiver, as shown in column 5, shows the extent to which this practical operation of mixing approached what is theoretically possible. Further than this, the equalizing effect of the operation is shown by a comparison of column 4, in which are given the percentages of silicon in the metal introduced, with column 5, which gives the percentages of silicon in the metal withdrawn.

Q. 9. Please say whether or not the test of the apparatus to which you have referred was under your personal control and direction.

A. It was.

Q. 10. From what were the silicon percentages given in columns 4 and 5 of your report determined?

A. They were determined from samples taken in duplicate from each portion of metal introduced into and withdrawn from the receiver. They were made by chemists in the employ of the Cambria Iron Co., to whom I sent the samples properly numbered, receiving in return, corresponding reports of silicon contents.

Q. 11. By whom and for whom was this report prepared?

502 A. The report was prepared by me, for and at the request of Mr. Joseph Morgan, Jr., chief engineer of the Cambria Iron Co.

Q. 12. Were the chemists who made the silicon tests embodied in this report, informed as to the origin of the test pieces or the purpose for which the tests were made?

A. I do not know positively as to this, but I do know that I took pains to conceal from them the position in the schedule of any of these tests, so that they had no idea of the relation which one bore to another.

The report referred to by the witness in the preceding answer is offered in evidence and marked "Defendant's Exhibit Tabular Record Fixed Mixer."

(Here follow photolithographs marked pp. 502*a*, *b*, & *c*.)

Complainant's counsel provisionally objects to this exhibit, reserving the right to object and give reasons after cross-examination.

Q. 13. Have you made any representation of the operations with the fixed receiver in any other form than the tabular report already referred to?

A. Yes.

Q. 14. Will you please produce the same and state what it is.

A. These four sheets of drawings give this record in graphical form, containing the same information as that given on the three sheets of tabular record. In these four sheets of graphical records the dates are stated at the top of each page; the times are shown by vertical lines; each sheet containing the record of one day, begin-

ning at 6 p. m. In this graphical record the silicon content of the blast-furnace iron which was delivered to the receiver is shown by a series of points, connected by a full black line; the silicon content of iron actually withdrawn from the receiver is shown by a series of points connected by a broken line composed of long dashes; the theoretical silicon is shown by a series of points connected by a dotted line, while the amount of iron put into, withdrawn
503 from and remaining in the receiver is shown by a broken line composed of alternate dashes and dots. The graphical sheets contain scales at one side for convenience in reference taken in connection with the various lines which I have just described.

Q. 15. Say whether or not the graphic and tubular records to which you have referred represent truly and correctly your operation and the results of the operation with the fixed receiver?

A. The tubular and graphic records which I have presented represent the operation correctly.

The four sheets of drawings referred to by witness are offered in evidence and marked "Defendant's Exhibit Graphic Record Fixed Mixer."

(Here fol ow diagrams marked pp. 504*a*, 504*b*, 504*c*, & 504*d*.)

Complainant's counsel objects to the graphic representations provisionally, reserving a right to object fully and with reasons after cross-examination.

Q. 16. During the operations with the fixed mixer under your charge, as stated, were any difficulties encountered? I wish to know whether or not, as a matter of fact, the apparatus was used continuously and successfully?

A. The apparatus was used continuously as desired throughout the period of time stated, and its operation proceeded without difficulty.

Q. 17. Say whether or not any change was made in the construction or mode of operating the blast furnace or the converters of the Cambria plant during the use of the fixed mixer between them.

A. There was no change made, except that all or a portion of the Bessemer converter charges was taken from the fixed receiver instead of from the other usual sources.

Q. 18. Say whether or not converter charges of metal exclusively from the fixed mixer were treated?

A. I don't understand the question.

Question withdrawn.

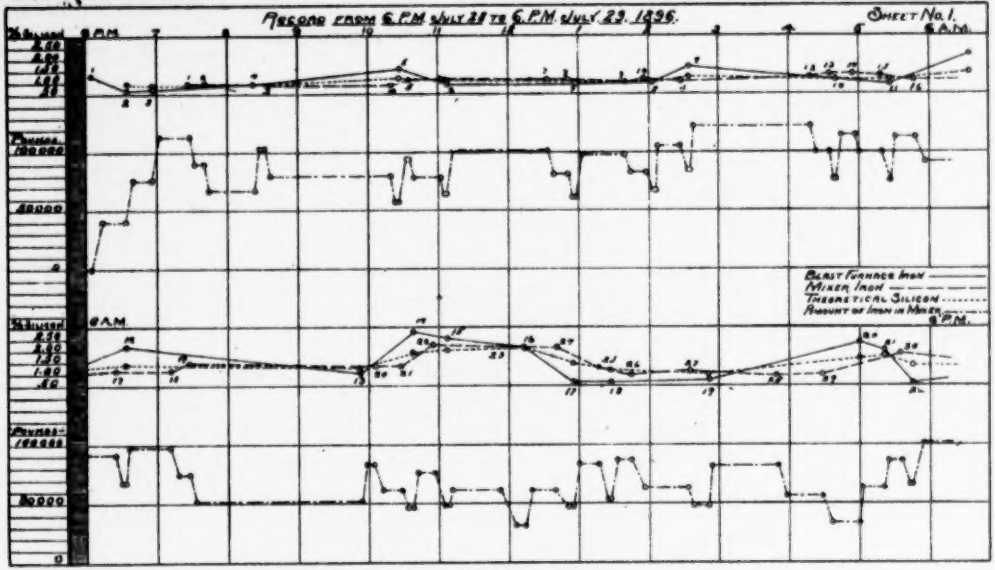
504 Q. 19. Say whether there were converter charges for which the molten pig metal was obtained wholly from the stationary mixer or receiver?

A. A number of entire converter charge- were obtained from the fixed receiver.

United States Circuit Court
Western District of Pennsylvania

Carnegie Steel Co Limited
& Cambria Iron Co.

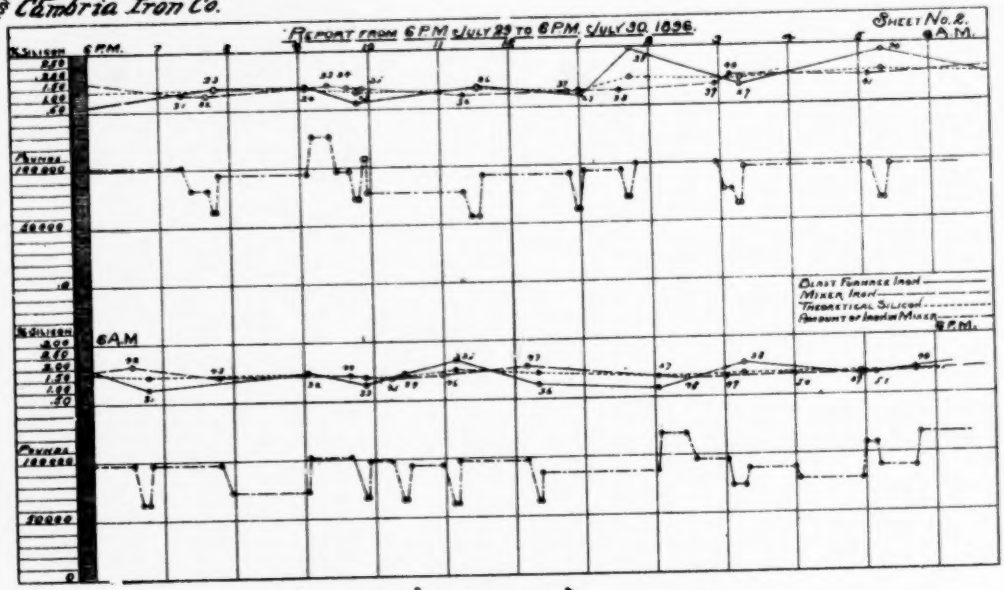
Defendants' Exhibit Graphic Record, Fired Mixer
Sheet 1.
Robt C Totten
Examiner.



Carnegie Steel Co.
vs.
Cambria Iron Co.
} p. 504. a

United States Circuit Court
Western District of Pennsylvania
Carnegie Steel Co Limited
& Cambria Iron Co.

Defendants Exhibit Graphic Record, Fixed Mixer
Sheet 2.
Robt C. Totten
Examiner.



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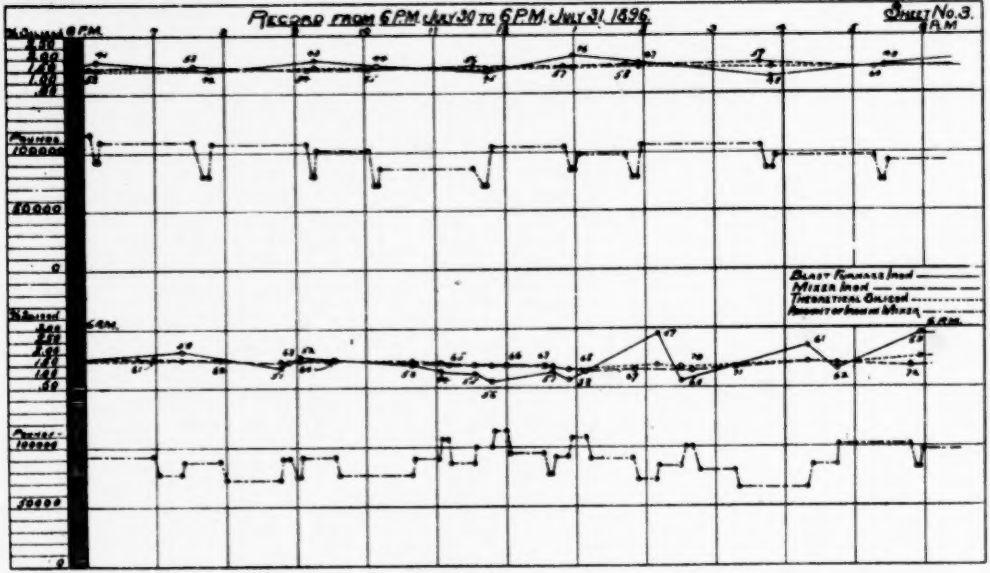
Cambria Iron Co. }

United States Circuit Court
Western District of Pennsylvania
Carnegie Steel Co Limited
& Cambria Iron Co.

Defendants Exhibit Graphic Record Fixed Mixer
Sheet 3.
Robert C Totten
Examiner



Carnegie Steel Co.
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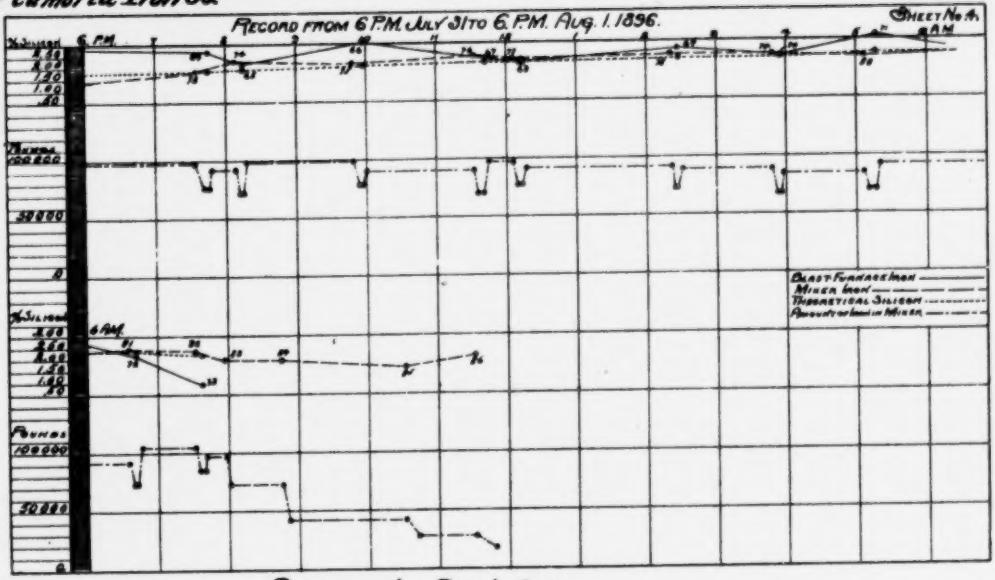
United States Circuit Court
Western District of Pennsylvania

Carnegie Steel Co. Limited
& Cambria Iron Co.

Defendants Exhibit-Graphic Record, Fixed Mixer
Sheet 4.
Robert C. Totten
Examiner.



Carnegie Steel Co.
vs.
Cambria Iron Co.
} 1.504d

Q. 20. Say whether or not these converter charges exclusively from the fixed receiver were successfully blown into steel?

A. They were.

Q. 21. Say whether or not the metal was taken from the stationary receiver for the converters at random? That is to say, regardless of the character of the metals or without special knowledge of what was coming out?

A. It was.

Q. 22. Say whether or not the metal from the fixed receiver was taken through your ordinary converters and went into your commercial product with your other steel?

A. The metal from the fixed receiver was treated as usual in our Bessemer converters, and formed part of the regular Bessemer output at the time stated.

Cross-examination by counsel for complainant:

X Q. 23. What was the object of the construction of the experimental mixer and of the experiment made with it? if you know.

A. As I understand it, this was done for the purpose of learning the facts regarding the operation of a receiver of this size and kind.

X Q. 24. It was only then, in regard to the operativeness of a mixer of the size shown in the drawing "Exhibit Experimental Mixer" as compared with some other mixer of a different size. Is that so?

Objected to, it not appearing that this witness who worked under orders, was informed as to all the purposes for which the apparatus was constructed and operated.

505 Objection objected to because the purpose of the cross-examination at present is to find out what the witness did know and where he got his information.

A. I made no comparisons and merely conducted a test of the receiver which I have referred to at the time stated.

X Q. 25. So far as you know, or were informed, by the person or persons who instructed you in regard to this experiment, the only object was to ascertain the facts regarding the operation of a receiver of the size and kind shown in your drawing "Experimental Mixer." Is that so?

A. My entire object as here-before stated, was to ascertain the facts connected with the operation of the receiver which I have described.

X Q. 26. To what point, or points, was your attention specially directed, either on your own suggestion, or in consequence of instruction from others, in regard to the operation of the experimental mixer in question?

A. I cannot recall any further instruction regarding the operation than the general one to take charge of a test and ascertain the facts.

X Q. 27. Why, then, does your attention seem to have — particu-

larly directed to the silicon content of the molten metal at different stages and at different times of the operation?

A. Because that was part of the facts connected with the operation.

X Q. 28. And the other facts, whatever they may be, you have failed to take notice of or report?

Objected to. The reports in evidence failing to bear out the assumption in the question.

A. I do not know what facts you may refer to.

X Q. 29. Then, speaking of the silicon as part of the facts, I understand you have no idea of what the other part of the fact is? Have you?

Objected to, the reports presented showing many facts other than those recited in the question.

506 A. In addition to the facts relating to silicon, I have also reported other facts relating to quantities of metal put into and withdrawn from, and remaining in the receiver, together with the dates and times of such steps in the operation.

X Q. 30. And these facts just referred to in your last answer are facts having relation to the operation of the experimental mixer which you were to ascertain and make note of as the result of the experiment, are they?

A. These facts are those which I had observed and of which note was made.

X Q. 31. Who gave you the orders referred to in the objection of counsel to the 24th question?

A. Joseph Morgan, Jr., chief engineer of the Cambria Iron Co.

X Q. 32. That objection states that you were not informed as to all the purposes for which the apparatus was constructed and operated, or that it did not so appear. Have you stated all the purposes in regard to the construction and operation of this experimental apparatus as to which you were informed by Mr. Morgan, or any other officers or employees of the company?

A. As I understand it, the purpose of the operation of the fixed receiver to which I have referred, was to ascertain the facts regarding the same and to learn the practicability of operating a receiver designed some years ago by a Mr. Deighton of England.

X Q. 33. This, then, was regarded as an experiment, was it not?

A. Yes.

X Q. 34. Why was this experimental mixer used only for two or at most, three days? If such be the fact?

A. I do not know, altogether; as my instructions were to conduct a test of it during one week's run of our Bessemer depart-
507 ment, which I did, the test covering a period of almost four days, instead of as stated in your question two or three.

X Q. 35. This experimental mixer is not still used at the Cambria iron works, is it, in relation to the Bessemer direct process?

A. I believe it is not, but I do not know personally of my own knowledge.

X Q. 36. Was this mixer built by employees of the company or other laborers under your special supervision and direction?

A. It was not.

X Q. 37. Do you know the party—any of the parties who personally directed the construction of this experimental mixer?

A. I believe it was built under general direction of Mr. Morgan, chief engineer of the Cambria Iron Co. I don't know by whom.

X Q. 38. Now please tell me who assisted you in the experimental operation of this experimental mixer?

A. I had two observers who assisted in taking the notes relating to the operation, one on day turn and one on night turn. In addition to which the actual work of the operation was conducted by the employees of the Cambria Iron Co. The observers were Alexander K. Hamilton and Lester R. Clifford. I do not know the names of the workmen.

X Q. 39. Do you know anything about the Deighton patent to which you have referred?

Objected to as improper, incompetent and not in the line of cross-examination.

A. I do not know that I referred to any Deighton patent. I do know and have seen a Deighton patent.

X Q. 40. State whether the experimental mixer which you have referred to in your examination-in-chief, and which is shown
508 in the drawing you have presented, was constructed in substantial accordance with the description given in the Deighton patent, which you do know of?

Question is objected to as not in the line of cross-examination, and as referring to matter wholly outside of those respecting which the witness was interrogated in chief, and complainant's counsel is notified that the witness will be treated as his own respecting such new matter.

In view of the objection just made, counsel for complainants inquires of counsel for defendants whether or not the experimental mixer used by the witness Thackray was not constructed and experimented with with a view to comparing it or its operation with the device shown in the Deighton patent.

Counsel for defendants replied that such was one of the purposes leading to the construction and test of the stationary receiver, but that it has not been his purpose to make such a comparison by or through the present witness, and that as a matter of fact, he has not gone into a consideration of the Deighton patent with this witness either on or off the stand.

Last question withdrawn.

X Q. 41. State of what material the experimental mixer was constructed?

A. It was made of plate steel or iron and lined with firebrick.

X Q. 42. Was it covered?

A. It had a dome-shaped cover, as is clearly shown on the drawings which I have presented.

X Q. 43. What was the cover constructed of?

A. The cover was constructed of firebrick contained within a ring, the cover being in the shape of flat arch or dome.

X Q. 44. How was this cover attached to the mixing reservoir?

A. It was laid loosely on the upper portion of the walls of the receiver.

509 X Q. 45. What was the object of the cover and why was it left loose, if you know?

A. I cannot answer as to this; the cover was not moved during the operation.

X Q. 46. In what way was the metal tapped from this mixer?

A. By cutting out the clay bott from the tapping hole in a manner similar to that used when tapping out the cupola.

X Q. 47. Why were there, as apparently there are in the drawing, three tap-holes in the side of the mixer?

A. There were three tap-holes, as shown, in order to enable the workmen to withdraw metal from either, as desired, but throughout the entire period, with the exception of the latter part, but one hole was regularly used.

X Q. 48. Which hole was that?

A. The upper one, which, as shown by the drawing, is located about 18 inches above the very lowest part of the bottom.

X Q. 49. Why, at the latter end of the operation did you change from the upper hole to the lower hole?

A. The lower hole was a draining hole in order to permit the receiver to be completely emptied at the end of the operation, as this naturally could not be done through the upper hole.

X Q. 50. What do you mean by the "end of the operation"?

A. The end of the operation was the time at which the week's work of the Bessemer department was completed. After which there was no further need for metal.

X Q 51. Was this draining of the mixer through the lower tap-hole successfully accomplished?

A. It was.

X Q. 52. That was at the period when your report termi-
510 nated, was it not? Or was the receiver frequently drained during the three or four days occupied by the experiment?

A. It was not frequently drained, and was only emptied as heretofore stated, at the time when the week's work of the Bessemer was finished.

X Q. 53. I asked you in my last question whether that last draining was at the period when your report terminated.

A. It was at or about that time.

X Q. 54. Then, what was done with the 17,000 pounds of metal remaining in the mixer when your experiment terminated?

A. Most of it was drawn into the receiving ladle of the Bessemer steel works and used in a manner similar to other portions withdrawn. A small quantity was run to the dump to be recovered as scrap. As I understand it, this latter quantity was considerably less than a ton.

X Q. 55. Were there any difficulties experienced in the sculling of the mixer during the operation of the experiment?

A. As far as I know, there was practically none, but, I believe, there was a very small amount of scull remaining in the receiver after the completion of the operation.

X Q. 56. Your drawing is entitled "Experimental Mixer," and you generally use the word "receiver." I suppose I may understand that the receiver and experimental mixer are the same thing?

A. You may.

X Q. 57. Where is this experimental mixer now, if you know?

A. It is still in its original position, in the works of the Cambria Iron Co.

X Q. 58. What experience have you had in the operation of the direct process in connection with Bessemer converter practice?

Objected to as not proper cross-examination.

511 A. I have had no personal experience immediately connected with the working of the direct process in connection with Bessemer practice, but, I have had charge of direct practice in connection with other refining operations, notably, in connection with what is known as the Krupp Bell dephosphorizing process.

X Q. 59. As I understand your testimony-in-chief in regard to the experimental use of the mixer, shown in your drawing "Exhibit Mixer," there were five blast furnaces used in this experiment in connection with the mixer. This is a fact, is it not?

A. The reports made for me on this subject showed this to be so.

X Q. 60. You have stated how they tapped the mixer when drawing molten metal from it for the converter. Will you also state how they stopped the tap-hole after drawing out a charge?

A. The tapping hole was stopped in the manner similar to that used in stopping the tapping hole of a cupola. This was done by the workmen in charge of that part of the operation, who, for this purpose, placed a clay bott on the end of a bott stick, and who, at a given signal, pushed the clay bott into the hole and held it there temporarily until it had became hardened in the usual way. The signal was given to notify him when the required quantity had been tapped into the receiving ladle. The clay bott to which I refer is a conical lump of plastic clay and the bott stick is an iron rod provided with a disc at one end on which the bott is placed, this bott stick being provided with a suitable handle by which it is grasped.

X Q. 61. In your report of the operation of the experimental mixer, I notice that the amount taken out from time to time was always a certain number of thousand, and sometimes even of tens of thousands of pounds. How did you manage to draw from the mixer by the means you have described such an exact quantity of molten metal?

512 A. The figures stated, owing to the necessities of an operation of this kind, are, to a certain extent, approximate, and stated in round thousands of pounds.

X Q. 62. Then, to that extent, your report is not accurate, is it?

A. That is so.

X Q. 63. When you drew molten metal from the mixer in the manner you have described and plugged up the tap-hole after drawing the iron, did the iron cease flowing from the mixer just at the time when you set the plug?

A. At all times when I saw it, it did.

X Q. 64. Was there any apparatus or device for weighing attached to or directly connected with the mixer by which you could ascertain the amount drawn therefrom?

A. There was no weighing apparatus attached to the mixer or receiver to which I have referred.

The testimony of this witness as to the experiment made with the experimental mixer referred to and all his report and drawings illustrative thereof, are objected to for the reason that it was an experiment made in the absence of the complainants, or any officer of the complainant company or complainants' counsel, and was made without any notice to them, or any of them, to be present at such experiment, and for this reason the complainants contends that the experiment is utterly incompetent, and that all testimony in regard to it must be excluded from the consideration of the court.

Redirect examination:

R. D. Q. 65. Please explain in what sense you said that your report was inaccurate as to the weights of the metal?

A. The weights of the metal going into the receiver were determined in most cases by weighing the ladles on track scales connected with the Bessemer steel works, as I have already stated. The amount of metal in the receiver at any time, and the amount withdrawn were determined by measuring the height of the
513 top of the bath from a certain fixed point above it, and it is in consequence of this method of measuring instead of actual weighing that the questions were stated to be approximate. This measuring, however, was done with the greatest care possible.

Recross-examination:

R. X Q. 66. The method of ascertaining the amount drawn from the mixer after each tap would be rendered uncertain by the fact of the existance of an increasing quantity of graphitic carbon on the surface of the molten metal in the mixer, would it not?

A. This would be true to a certain extent, but the records do not show that this amounts to much. An inspection of the figures relating to quantity put in and quantity withdrawn will show that these columns agree as to the totals, with the exception of the small amount remaining in at the end of the operation, as heretofore stated.

R. D. X Q. 67. And even then, no measurement of the mixer could yield a result represented by three or four cyphers at the end of the number of pounds removed, could it?

A. I do not understand that question.

R. D. X Q. If you were to measure the distance from the top of the interior of the mixer to the surface of the iron and knew by previous measurement of the distance of the top of the receiver to the previous *service* of the metal, a multiplication of the area of the cross-section of the mixer by the ascertained height of the portion of metal removed would not give you any result either in cubic feet or in pounds which would be even hundreds, thousands, or ten thousands of pounds, would it?

A. As against the hypothesis advanced regarding the correctness of the method of obtaining quantities by measurement you have the record which shows that the totals of the amount put in and taken out practically agree.

R. D. 69. Is that the best answer you can give to my question?

514 A. I had not finished my answer when you interrupted me with your last question. As against your hypothesis that quantities could not be obtained to within tens of thousands of pounds. I can say that in the body of a cylindrical vessel 9 feet in diameter, 1 inch of vertical height of iron would be a little more than a gross ton in weight so that if the measurements were correct to an inch, the error could not be greater than this.

X Q. 69. Do you pretend that at each of the repeated tappings from the mixer, you measured the height from the top of the mixer to the surface of the molten metal over such a large area of molten metal and ascertained the height to within an inch in every case? It is not a question as to what might have been done, although what you suggest I think to have been impossible, but what actually was done in the present case.

A. I did not make the measurements myself, personally.

R. X Q. 70. Can you tell me at what point in the mixer this vertical measurement was made and whether or not the cover was removed after each tapping for the purpose of making this measurement?

A. The point of measurement was somewhere near the center, the exact location I cannot give. The cover was not removed during the operations, as heretofore stated by me.

GEO. E. THACKRAY.

515 JANUARY 15TH, 1897.

Met pursuant to agreement of counsel at the office of Dr. James H. McClelland, Fifth and Wilkins Aves, Pittsburgh, Pa.

Present: William Bakewell, Esq., counsel for complainant, and James I. Kay, Esq., counsel for defendant.

Testimony of Dr. James H. McClelland.

Dr. JAMES H. MCCLELLAND, a witness called on the part of the defendant, being duly sworn, deposes as follows, in answer to questions put to him by Mr. Kay:

Q. 1. State your name, age, residence and occupation.

A. James H. McClelland; age 51; residence Pittsburgh; occupation a physician.

Q. 2. Do you know anything of the casting of a twenty-inch gun at the Fort Pitt Foundry of Knap, Wade & Company or Knap, Rudd & Company?

A. Yes, I have a rather distinct recollection of the transaction.

Q. 3. About when did it occur, according to your recollection?

A. That I would have to say approximately, because I have nothing definitely in mind to fix it, except that I would say about 1863 or '64. That was the time that Major Rodman then was staying at our house.

Q. 4. What had Major Rodman to do with the casting of this twenty-inch gun?

A. Well, it was cast according to a discovery or principal which he devised for making hollow castings of large sizes.

Q. 5. Do you remember generally what that principle was?

A. The principle, as I have heard him explain it more than once, many times, was the casting of such matters with special reference to large ordnance, hollow, and his explanation of the neces-
516 sity for that was that the metal would cool from the inside as well as from the outside, and in that way it would be more even in its texture; that is my recollection of the reasons he gave for it. I can just say further that the reason I happen to know at all about this was, he was staying at our house and he and my father I think almost daily discussed the matter of this gun casting and similar things, and it became a matter with us of exact knowledge, almost. We understood his views of it and ideas in a way that we would not have done if it had not been discussed over and over again.

Q. 6. What relation was Major Rodman, if any, to you?

A. He was an uncle.

Q. 7. Were you present at the casting of this gun?

A. I was present at the casting of the gun, stood right beside Major Rodman while the gun was being cast.

Q. 8. Can you state generally as to in what way the gun was cast, where the metal was obtained and what was done with it?

A. Before the gun was cast I remember they discussed at our table, where such matters were talked about, the necessity for gathering up the metal from different sources; the reason given in that case was that they had no furnace large enough, no one furnace large enough, so when I went to see the casting I was quite prepared to understand just what occurred, and my recollection of it is very vivid. I remember of the metal being carried along troughs from three sources, three furnaces, some further, and some—perhaps one further off and one near the center, and another some distance from the pit. This metal was conveyed along troughs to a central pool and then run off from this pool into the mold. Whether that went off in one or two streams from that pot I am not clear. At least my recollection would be that there was a stream run off to each side of the drop, but I know they all three went into this pool.

Q. 9. And then from the pool into the gun?

517 A. It was conveyed into the mold.

Q. 10. Did you hear Major Rodman discuss at all the reason why the metal was carried into this pool?

Objected to as incompetent, and having no reference to the matter at issue in this case.

A. Yes, I did.

Q. 11. Please state about when you heard Major Rodman discuss this question, whether it was before or after the casting of the gun, and with whom he discussed it.

A. Well, I heard him discuss it very often, both before we went down to the Fort Pitt words and afterwards, because people were coming all the time, visitors, and discussing it, it was quite an event, you know. There were some army officers that were visiting here, and the whole matter was gone over more than once.

Q. 12. Do you remember what reason was stated for taking the metal from the furnace into this pool and thence into the gun?

A. Why, it was distinctly stated that it was in order to make the mass homogeneous, in order to mix the metals together, and convey them in a homogeneous mass into the little mold.

Q. 13. Did you ever hear Major Rodman state as to what would be the effect if they had not employed that pool?

A. Well, that was involved in that idea, you see, of course, he would say why; that is, if they put it in that pool to mix it before conveying it to the mold, it was because, if they did not mix it, it would be the other way it would go in different strata, you might say. That is the idea I got from it. I don't know whether I was correct or not.

Q. 14. How much attention did the casting of this gun attract? Were there others there outside of Major Rodman and those connected with the works?

A. There was a crowd of people there, I don't recall distinctly the names of anybody except those around the—I knew at the
518 time that there were many people, but just who they were I don't recall. I remember the manager, old Joe Kaye, who used more or less profanity. The whole thing is very distinct in my mind.

Cross-examination by W. BAKEWELL, Esq., counsel for complainant:

X Q. 15. What was the size of what you have designated as the pool into which the metal was run?

A. Well, at this distance of time I wouldn't be very clear as to that. From my point of view it looked like a pot or round vase there, I couldn't tell whether—it was possibly six feet across. My recollection of it as I saw the metal run into that, that it was a pool I would think six feet across, the length of a man across. Now that is as near as I can come from my recollection of it.

X Q. 16. Of what material was this pool constructed?

A. Well, that I wouldn't say positively; my memory don't carry me that far.

X Q. 17. Was it stationary or moveable?

A. Stationary.

X Q. 18. What description of furnaces was it from which the metal was run into this pool?

A. Well, my recollection of that is—that of course is also indistinct, but they were distinct structures built up across the three points in the works there.

X Q. 19. You don't then know what description of furnace was used?

A. No, I couldn't just say that.

X Q. 20. Were there any Bessemer converters used in connection with this operation you referred to?

Objected to as immaterial.

A. Never heard the name mentioned; don't recall that it was mentioned.

X Q. 21. Was the molten metal run from the furnace into this pit all at the same time?

A. All run in at the same time, three streams.

519 X Q. 22. And at the same time the metal was running into the pool it was being poured into the gun pit?

A. Yes, it was running out of this pool into the pit.

X Q. 23. It was running from the furnaces into the pool and from the pool into the pit all at the same time?

A. Yes, sir.

X Q. 24. Do you know anything about the character of the metal that was being used?

A. Well, I will not answer that until I think. I heard them discuss about that, but I don't recollect.

X Q. 25. Have you any knowledge as to the size or capacity of the furnace in which the metal was melted?

A. No, I couldn't say anything about capacity.

X Q. 29. Wasn't the chief reason, as you understood it, why these several pourings from furnaces and this pool was used, that they had no melting furnace, the capacity of which was sufficient to melt at one time a sufficient amount of metal for the casting?

A. That was distinctly the reason that they had to use it for three furnaces.

X Q. 27. How long did it take to cast this gun from this pool into the pit?

A. It seemed a long time to me, but I suppose it could be compassed in half an hour.

X Q. 28. And what you have described is all of the operation, so far as you recollect it?

A. All that relates to that.

X Q. 29. You have spoken of a great interest attached to the casting of this gun. Is it not a fact that this interest arose from the casting of a gun hollow instead of casting it in one piece and then boring it; and also in the large size of the gun being cast; are not those the points?

A. The first point was, the gun was being cast hollow; the second point was, that it was of enormous size; now the third point, to my mind, was that they had no big furnace and they had to mix

520 the metals from three furnaces to put it into that gun. In order to get the metal homogeneous, they put it in a pool and run it off.

By Mr. BAKEWELL: The foregoing testimony objected to on the ground that it is irrelevant, and has no connection whatever with the matters in this case.

(Signature waived.)

TUESDAY, *January 19th*, 1897.

Met at the office of P. T. Dodge, Esq., pursuant to agreement of counsel.

Present: P. T. Dodge, Esq., and James I. Kay, Esq., for defendant, and T. W. Bakewell, Esq., for complainant.

Testimony of J. S. Robeson.

J. S. ROBESON, a witness called for the defendant, and being duly sworn, deposes as follows in answer to questions put to him by Mr. Kay:

Q. 1. State your name, age, residence and occupation.

A. J. S. Robeson; age, 31; residence, Camden, New Jersey; occupation, metallurgical engineer.

Q. 2. Were you ever in the employ of the Edgar Thomson steel works of The Carnegie Steel Company, the present complainant, or its predecessors, and if so, during what period?

A. I was in the employ of that company for two different periods. First, in 1885 and 1886, about 14 or 16 months, and later in 1893 and 1894 for a period of about 18 months.

Q. 3. In what capacities were you employed during these two periods?

A. During the first period I was employed as a chemist in the steel-works laboratory, holding various positions from what was known as the silicon man to first assistant, having charge of
521 the general work. During the second period I was employed as special assistant to Mr. James Gayley, who was then general manager of the plant.

Q. 4. Where were you employed between these two periods and in what capacity?

A. I was in the employ of the Pottstown Iron Company, and occupied various positions in their steel works from that of chemist to assistant general manager.

Q. 5. When you were at the Edgar Thomson steel works, was there any system for the determination of the silicon in the blast-furnace metal? And, if so, please state whether your work — directly connected with this.

A. During the first period when I was with the steel company and during the very first four or five months of that period I was directly in touch with the system of determining silicons in the molten pig iron. The laboratory was so arranged that there was always one chemist on duty there during the whole of the 24 hours, whose work it was to analyze the sample of iron which was taken during the casting of the molten metal in the ladles at the blast furnaces, and to report the result of such analysis with all the despatch possible to the blower and scrapper in the converting mill.

Special messenger boys and a special system of taking the samples were employed in order to facilitate this arrangement, and to insure the delivery of the report to the converting mill before the molten iron which it represented was poured into the converter.

Q. 6. How many such chemists were so employed, and were you one of those chemists, and for what period?

A. There were three such chemists employed. I was one of them for some four or five months.

Q. 7. You state that you were employed there about 14 or 16 months at that time. Had you knowledge as to whether this system was continued during that time, and as to the general results of such analysis?

522 A. Being in the laboratory all this time, and having charge of the men who carried on this work after I ceased, I know that it was continued during all of that period. These analyses varied somewhat from day to day, ranging at that time *to* about, say, one and one-half per cent. of silicon to two and a half or two and three-quarters per cent.

Q. 8. Had you knowledge of analysis of the blast-furnace metal for sulphur during your first employment at those works; and, if so, about what variation was there in that?

A. I had some knowledge, but not as great as later on since fewer sulphur determinations were made at that time. The sulphur content was in the neighborhood of five-hundredths (.05) per cent., and varied usually in proportion with the silicon rising sometimes as high as seven-hundredths (.07), but never dropping very much below four-hundredths (.04).

Q. 9. I call your attention to the statement or table of analyses of metal in the Jones patent in suit, on page 1, line 29 to 43. Will you please state whether such analyses so given is an average of the regular working of the blast furnaces at the Edgar Thomson steel works during the time you were employed there?

A. Not as far as anything in my experience went at that time. I never saw such analyses as that.

Q. 10. In what way is this statement of analyses found in patent faulty or incorrect?

Objected to as leading, and assuming what the witness has not stated.

A. As I understand the analys*is* given in the patent, they refer to a number of ladles of metal which were taken from the blast furnace at one tap, and they are very abnormal in the extreme variation of silicon and sulphur which they show, the silicon ranging from sixty-six-hundredths (.66) up to four and fifteen-hundredths (4.15) per cent., and the sulphur from fifteen-thousandths (.015) up to one hundred and forty three thousandths (.143) per cent.

523 Q. 11. During this first period of your employment at those works what variation did you find on an average in the blast-furnace metal taken either from a single casting of a furnace, or different casts of furnace?

A. I have never seen a variation during my work at the Edgar

Thomson steel works at this first period of more than three-fourths (¾) of one (1) per cent. of silicon in any one cast, nor of more than one and one-half (1½) per cent. of silicon in any one day of any one furnace unless the furnace was being blown out or blown in, or had gotten into some trouble of which the management were aware, and when consequently we expected a great variation in silicon or sulphur. I do not recollect any similar figures as to sulphur since the determination of this element in the steel-works laboratory were not very frequent.

Q. 12. In your answer 5 you have described the custom of making a quick analysis on the blast-furnace metal of any particular ladle and delivering the same to the blower and scrapper in the converting mill. What was the necessity of making this quick analysis and how did it aid the blower and scrapper in his work?

A. The analysis was required so as to enable the men in the converting mill to know about what the content of silicon was in the molten metal, whether it varied much or little from the preceding charges, and he was thus aided in his judgment as to whether the heat would blow hot or cold and consequently whether it would need much, little or no scrap.

Q. 13. For the information of the court, will you please state what effect the addition of scrap to the converter charge had?

A. The scrap probably acts in two ways. If a charge contained more than a normal amount of silicon it will blow hotter than the normal or proper temperature, since the combustion of this additional silicon produces more heat. The scrap used contains little or no silicon. It consequently acts as a dilutant, reducing the percentage of silicon in the total charge; and in addition, since
524 it is cold and solid when put into the vessel, it consumes some of the excess heat in being melted.

Q. 14. You state in answer 3 that during your second period of employment at the Edgar Thomson works in 1893 and 1894, you were special assistant to the general manager Mr. Gayley. What were your duties in that position?

A. My duties at first were not clearly defined, and were very general. Later I took up the question of the quality of the product, this being governed to a large extent by the percentage of seconds-quality rails made, and this naturally led to keeping a record of the seconds, and of endeavoring to eliminate or eradicate the causes which produced any bad work in this direction.

Q. 15. When you took up this special work as to the "seconds," what percentage of seconds were they making, and you might give daily percentages and weekly percentages showing about the run of work?

A. I think that I cannot recollect clearly enough to state with any accuracy what the daily percentages were; they varied to a very large extent. The weekly averages at that time were about eight and one-half (8½) per cent., some weeks being perhaps a per cent. higher, other weeks a per cent. lower.

Q. 16. Have you any recollection of the highest point to which the daily averages of seconds would run?

A. I have no recollection of what the highest daily percentage might have been during this second period, but I have known this figure to reach sixteen (16) per cent.

Q. 17. Did you at or about that time ascertain the average percentage of seconds made in other steel-rail mills, and if so, in what way did you obtain this knowledge?

A. I have been in the habit for the last 8 or 10 years of visiting the different steel works in this country, and in the course of my various trips have seen all of the works with the exception
525 of two. Just previous to my going with the Carnegie Steel Company in '93 I had made such a trip, and once or twice during my connections with them I made similar trips, and know that with one and possibly two exceptions, the other rail mills were making a considerably lower percentage of seconds. The average in two cases that I recollect at present for a period of a month being in the neighborhood of three (3) per cent.

Answer objected to as being apparently based on hearsay.

Q. 18. On those different visits to other steel works stated in your last answer, made previous to and during your employment in the Edgar Thomson works, in what way did you obtain the knowledge as to the percentage of seconds made in those works?

A. In various ways. I cannot tell exactly how the result from each particular mill was obtained. In some cases I have been permitted to look at the records; in other cases it has been simply by word of mouth from the superintendent, his statements being largely governed, as far as I am individually concerned, by the rails that I saw in the mill.

The objection to the statement of the witness concerning the product of other mills is again objected to as hearsay.

Q. 19. When you made these visits to other mills, during the time you were in the employ of the Edgar Thomson works, were you sent for this purpose by the manager or other officer of the Edgar Thomson works?

Objection repeated.

A. On one occasion I was so sent; on the other occasion I think I made the trip on my own account.

Q. 20. What led to your being sent by the manager or other officer of the Edgar Thomson works to the mills?

A. A desire to know what the other works were doing, and, if possible, to take advantage of any such improvements as they might have made in their practice.

526 Q. 21. Had this trip anything special to do with the matter of the reduction of seconds?

A. Well, as the percentage of seconds might be called the indicator of the good or bad work of a mill, it naturally follows that the information sought was intended to be used in reducing the percentage of seconds.

Q. 22. How friendly, if at all, were these different mills, as to giving information as to the practice therein.

Question objected to as altogether irrelevant.

A. I really do not know how to answer such a question in any but a very general way. Some of the mills, or some of the men, perhaps, in the mills were very willing to give information, with almost no solicitation. In other cases considerable tact and diplomacy was required.

Q. 23. You have described the system of obtaining quick analysis of the metal to be used in the converter, and delivering the same to the blower and scrapper during the first period of your employment at the Edgar Thomson works in 1885 and 1886. Was this practice continued during the period of your second employment in 1893 and 1894?

A. The analyses so referred to relate only to silicons, and the practice was continued with the exception that a sample instead of being taken from the metal as it flowed from the blast furnace to the ladle was taken at the mixer as it was poured into the ladle. The results and the general method of handling the sample were used and delivered in approximately the same way.

Q. 24. As I understand your answer, the sample that was analyzed in this way represented the metal in a certain ladle or ladles tapped at that time from the mixer. Is this correct?

A. Yes.

Q. 25. What aid did this analysis of such ladle or ladles so tapped from the mixer give to the scrapper or blower?

527 A. It enabled him to know, as I have previously explained, whether the heat would blow hot or cold, and even if it was not received in time for the blowing of that particular heat, it enabled him to form his judgment as to the behavior of the following heat in a greater or less degree.

Q. 26. Did it assist him in the treatment or the handling of that heat for the following heat, and, if so, in what way?

A. He would judge from the result of this analysis whether it was of the partic-lar heat blowing or of one or two earlier heats, whether the heat was liable to blow cold; and in this case he would side-blow the heat at once, or if it were liable to blow hot, he would add scrap.

Q. 27. When you returned to those works in 1893, did you find any change made in the location of the chemical laboratory; and, if so, for what purpose?

A. There was a new laboratory in existence on my return there in 1893, which, I understood, had been erected quite recently, say in 1892. This laboratory was very much closer to the converting mill than the old or main steel works laboratory, and it had been so located in order to facilitate the work of the converting mill; that is, so the samples could be delivered to the laboratory more quickly, and the results reached the converting mill sooner.

Q. 28. You have referred to "side-blowing." Please explain what this means and for what purpose it was employed.

A. Side-blowing is a mill or shop name which is used to indicate that the vessel during the time of the blow has been turned partly to one side, so that some of the tuyeres in the bottom are exposed, or nearly so, and the blast coming through these tuyeres either sweeps across the face of the metal or else travels through a very thin bath of it, and consequently very much more iron is oxidized than is usual in the process. In the Edgar Thomson plant there is a heavy brick wall just behind the converters. When the
528 converters are turned on their side, as described, the flame strikes against this wall, and the heat is to some extent reflected back into the vessel.

Side-blowing is employed to increase the heat of the blow, and I am under the impression that at first it was thought that this reflected heat was of great advantage, but as the method is employed in other mills where the before-mentioned brick wall does not exist, I consider that the greatest result comes from the combustion of the iron, much of which is left in the bath in the form of oxide.

Q. 29. Was there anything in the converter practice in those works, during your employment there in 1893 and 1894, which showed whether the metal received from the mixer was regular in silicon content or not?

A. As far as the silicon content alone is concerned, the analyses made of the mixer metals would best indicate that. The practice in regard to taking these mixer metal samples for analyses varied a great deal, sometimes but one sample would be taken from five or six ladles. At other times a sample would be taken from every other ladle, and in the latter part of '93, or the beginning of '94, an order was issued that the sample should be taken so as to represent two ladles. This, I believe, was after that strictly adhered to.

In addition to the analysis which related only to the silicon, there were two other facts which betrayed irregularity. The variation in the percentage of heats which were side-blows, this ranging from nothing up to 90 per cent. in 24 hours, on one or two occasions that I recollect, and also the variation in the length of the blow, this ranging from 11 minutes to 20. It cannot be said that these two facts betrayed irregularity of silicons alone, since a difference in the initial temperature of the metal would also produce a like irregularity.

529 Q. 30. So as to make this clear will you please state what rendered this side-blowing necessary, as you understood the practice there?

A. As I understood the practice there side-blowing was rendered necessary by a lack of sufficient heat in the metal, which lack of heat would be occasioned by too small content of silicon or a too low initial temperature.

Q. 31. During this time had you at your command the analyses of the metal drawn from the mixer?

A. They were always at my command, and on several occasions for long periods of time, say two or three weeks in each period, I made it a practice to daily examine these records for the purpose of

endeavoring to find out whether the variation in these analyses produced any bad results in the finished product.

Q. 32. Had you also at your command analyses of the blast-furnace metal produced in those works; did you examine those analyses?

A. I saw those analyses quite often, though I never kept any regular list of them as of the mixer analyses.

Q. 33. I call your attention to the analyses of blast-furnace casts and ladles taken from the metal mixer at these works as given in answer 9 of the testimony of James Gayley. Referring to analyses of metal taken from the metal mixer, will you please state whether or not the variations between successive ladles as found therein shows a fair average of such variation and defective ladles as shown by the analyses made in 1893 or 1894 as you recollect them?

A. Considering this list in the light of the analyses of which I was acquainted in 1893 and 1894, I should not consider it an average list. The variations shown here are very gradual, rising and falling by small steps. This was not always the case in 1893 and 1894, and in fact it was not often the case. The steps were much greater. The variation on occasions being as much as six-
530 tenths (.6) of a per cent. and on many occasions as much as five tenths (.5) of a per cent. between successive analyses of casts.

Q. 34. I call your attention to the analyses of blast furnaces as shown in this record given by Mr. Gayley. From your examination of these analyses, is there anything which indicates the number of furnaces from which metal was then being drawn?

A. There is nothing which indicates that clearly.

Q. 35. Referring to the blast-furnace practice in 1893 and 1894, while you were employed at those works, how nearly could they control the product from any individual furnace as to silicon content, and the regular running of such furnace?

A. The furnaces were under very much better control as far as silicon content were concerned than they had been 8 or 10 years previous, and as far as I could judge from the analyses of the blast-furnace metal the silicon could be kept within five or six tenths (.5 or .6) of a per cent. of any one point when the furnace was in good working condition, and if low silicon metal was aimed at the limit of variation was less.

Q. 36. I see in this analyses of blast-furnace metal given by Mr. Gayley, considerably more variation in silicon content than you state. What does this indicate?

A. As there is nothing to show in this list from what different furnaces these various analyses were claimed, it is impossible to answer this question without assuming that certain of the similar results were obtained from the same furnace. If we make such an assumption it would indicate that one furnace had during the 24 hours here shown, produced metal contained between .2 and 2.10 per cent. of silicon; that another furnace had produced metal ranging from about 1.30 to 1.60 per cent., and that another furnace had produced metal ranging from 0.75 to 0.86 per cent. or in that neigh-

borhood. This would indicate that these furnaces were being
531 intentionally run at about the percentages indicated either on account of economy in the special mixture of ore or because some condition of the furnace itself required it.

Q. 37. For the information of the court will you please state in what way the percentage of silicon in blast-furnace metal can be controlled and regulated?

A. My experience in blast-furnace work has not been sufficient for me to give any such explanation, as I have only had to do with the products of the furnace and can only testify as to such products and such analyses as I have been brought in contact with.

Q. 38. How close to any one standard have you known metal from a blast furnace to be in percentage of silicon?

A. I had experience at one time in 1891 and 1892 at the Pottstown Iron Company, where the variation of silicon in the blast-furnace metal was maintained within three-tenths (.3) per cent. for periods extending over several weeks, and when a variation greater than this did occur it never exceeded except for very small amounts five-tenths (.5) per cent.

Q. 39. Where were the mixers in the Edgar Thomson works located with relation to the converter?

A. They were quite some distance away, possibly ½ of a mile, being much nearer the blast-furnace plant than the converting mill.

Q. 40. Did they have any cupola furnaces in the works for remelting metal used for conversion?

A. They completed the erecting of two such cupolas very shortly after I went there in 1893. These were located quite near the mixers. They were used for melting scrap and such off metal as they might have, the molten product being put into the mixer and used together with the blast-furnace metal for conversion. As near as I recollect these cupolas were run only at irregular intervals, possibly only when sufficient off metal and scrap had accumulated to warrant their continual operation for several days.

532 Q. 41. Am I correct in my understanding of your testimony that the metal remelted in these cupolas was introduced into the metal mixer, and permitted to commingle with the blast-furnace metal therein?

A. I do not wish to be understood as saying that this cupola-melted metal was run directly in the mixer, but it was, as is customary with cupola practice in this country, run into a ladle. This ladle being then shifted and run behind the mixers into which the metal was poured. I also on one or two occasions saw the ladle run below the mixers, and the mixer metal poured into the ladle. This was not, however, the usual practice.

Q. 42. What do you mean by off metal?

A. Off metal is pig iron which is not salable, or if salable only at reduced price, and this on account of its having an excess or a deficiency in some of its chemical constituents, as for instance if the silicon should be excessively high, say from four to five per cent., or the phosphorus sufficiently above the Bessemer limit, 0.10 per cent.,

to prevent its being used for that purpose; or again, the sulphur might be high enough to produce a like result.

Adjourned to meet at the same place tomorrow, January 20, 1897.

WEDNESDAY, *January* 20, 1897.

Met at the same place pursuant to adjournment.
Present: Counsel as before.

Direct examination of J. S. ROBESON continued:

Q. 43. I call your attention to your answer to question 41, which does not make quite clear what was the customary practice in handling the metal remelted in cupola. Please state what the customary practice was in handling this remelted metal.

A. Whenever I saw these cupolas used the customary practice was to put the metal (molten) from them into the mixers containing the molten metal from the blast furnaces.

533 Cross-examination by Mr. BAKEWELL:

X Q. 44. During the time of your second employment at the Edgar Thomson steel works, when the mixer was in use, was it not the practice only to analyze the metal for every other charge in the converter and not to analyze the metal for each?

A. I think I so stated that in my direct testimony. It is correct.

X Q. 45. Was not the metal for analysis taken from the charging ladle when it was at the converter, and just before the metal was poured into the converter.

A. That is correct. My answer to question 23 was incorrect. I should have said there that the sample was taken from the metal after it had left the mixer.

X Q. 46. Was it not also a fact that the analysis of the metal of each heat that was analyzed was not completed until after the conclusion of the blowing and conversion of that heat?

A. That is correct and you will find that I drew attention to this fact in my direct testimony stating that the silicon determinations so made governed succeeding heats or in some cases heats because it has not always been the practice to analyze the molten metal for every other blow. If there was any delay in turning up the vessel to commence the blow it would be quite possible to have the silicon analysis on hand before that blow was under way.

X Q. 47. Did not the possibility of doing this indicate that the metal of successive heats as it was brought to the converter was substantially uniform in character although drawn at different times from the mixer.

A. Not necessarily so, since it is a practical impossibility to make a silicon determination including the time required for sampling quickly enough to reach the operator in every case before the blow is under way and with the present demand for rapid work
534 many chances as to the composition of the metal must be taken. This question is rather misleading since it says that

the metal represented by this analysis is taken at different times from the mixer. It is taken at successive times from the mixer and in the case of the two ladles represented by an analysis the time between the first and second ladle is just sufficient to change the positions of the ladle.

X Q. 48. But, as I understand the facts from what you have said, the experience at the works was such that it was found practically safe to rely upon the analysis of the metal supplied to the converter at one blow as representing the character of the metal which would be drawn from the mixer and brought separately to the converter for the next blow or blows. Am I right in so understanding?

A. If by practically safe is meant that the best results would be obtained they certainly are not reached, since the blowing at Edgar Thomson was at the time I was there the most irregular of any that I had ever seen.

X Q. 49. But whatever may be your opinion as to the character of the blow, it is a fact, is it not, that during the time the mixer was in use, the men at the converting department were given, for the purpose of guiding them as to the character of the heat they were working, not the analysis of that particular heat, but the analysis of metal which had been drawn separately from the mixer for the next or second preceding heat, and that they did as a matter of fact rely upon such prior analysis to determine the character of the heat then under treatment?

A. At one time they only had an analysis in every five heats, but later (and this during the time I was there) it was as you have stated, and could not be otherwise since there is no known method of furnishing the analysis any more quickly.

X Q. 50. You have spoken of the number of seconds or the percentage of second quality rails at the Edgar Thomson steel
535 works during the second period of your employment. Have you not included in this statement of the percentage the third quality or bad rails which are not fit for use at all but are melted up as scrap?

A. No; I have not included what were known as bad rails in the general percentage statement that I made.

X Q. 51. Was it not a fact that at the Edgar Thomson works at that time it was the practice to include the bad rails or thirds in the daily reports of seconds without distinguishing between them?

A. No, sir; in the large report sheets which were given to me every morning and which I worked over for a number of months the seconds and bad rails were reported separately.

X Q. 52. During the period in which you say the percentage of seconds was eight and a half per cent. for the weekly average and a higher per cent. for a daily percentage, was not the practice of rolling ingots directly without reheating being followed at the works?

A. Yes.

X Q. 53. Did not this practice of direct rolling without reheating tend to increase percentage of seconds and thirds?

A. Unquestionably. There were a number of changes made in

the mill practice both in converting and rolling mills by Mr. Gayley intended to improve the product.

X Q. 54. Have you had any experience in the charge or operation of blast furnaces?

A. I have had nothing to do with blast furnaces except to use their product since 1892, when I was assistant to the manager of the Edgehill furnace at Edgehill, Pennsylvania, unless the opportunities which I had for examining the records of the Edgar Thomson furnaces could be so construed.

X Q. 55. Referring to your answer to question 28, were not the variations of which you there speak observed in Bessemer pig, and, if so, what was the percentage of silicon contained in such pig?

536 A. The pig iron referred to was for use in basic Bessemer converter. During the period referred to there were two grades of such pig iron made, one containing from three-quarters of one per cent. to one per cent. of silicon, and the other below five or six tenths of one per cent. I am not sure which of the latter figures was correct.

X Q. 56. Then was not the variation in silicon from the average about 60 per cent.?

A. In the case of the higher silicon the percentage of variation is about 25 per cent. In the case of the lower silicon the percentage of variation is about 60 per cent., and it can naturally be seen that this percentage figure is very variable, depending on total percentage of silicon in the metal, and consequently misleading.

X Q. 57. Referring to your answer to Q. 39, in which you state the distance of the mixer at the Edgar Thomson works from the converters. Please state further the distance of the mixers from the blast furnaces?

A. As the blast furnaces extend along in a line it is somewhat hard to answer this, but I should think that the nearest blast furnace to the mixers was not more than one-fifth of the distance between the mixers and the converting mill, and the furthest blast furnace is, I should think, about as far away from the mixers as half the distance between the mixers and the converting mill. It must be understood that the distance referred to between the mixers and the converting mill is over the track on which the ladle travels and not the air-line distance.

X Q. 58. How is the metal taken from the furnace to the mixer?

A. In ladles.

X Q. 59. Of what capacity?

A. My impression is that they were about twenty tons.

X Q. 60. Will you please reflect a little and see if you do not remember that these ladles were ten tons capacity each?

537 A. I have no better recollection that what I have said.

X Q. 61. And the ladles for taking the metal from the mixer to the converter were of less capacity than the ladles by which the metal was brought to the mixer, were they not?

A. I have not stated what the capacity of the ladles taking the metal away from the mixer was. If my recollection of the size

of the ladles bringing the metal to the mixers is correct, then the ladles taking the metal away were somewhat smaller, since they held from thirty to forty thousand pounds.

X Q. 62. What did you understand to be the function of the mixer used at the Edgar Thomson works during the second period of your employment?

A. The mixers received and stored the large amount of metal made at each tap by the various blast furnaces and delivered it in smaller lots of regular weights and at regular intervals as required to the converting mill. During this storage there was naturally a mixture of the molten contents of the mixers.

X Q. 63. What was the ordinary rule as to the mode of supplying the mixer with molten metal?

A. The rule was to keep the mixers full and the taps from the blast furnaces were divided between the two mixers. This was the usual custom, and my impression is that there was an order to that effect.

X Q. 64. You have spoken of the practice of side blowing as being resorted to when the converter charge lacks silicon or has a too low initial temperature. Is not such side blowing wasteful because of burning up of the iron, and is it not to that extent an evil necessary to correct the defects in the character of the metal?

A. It is wasteful of iron, and I believe it is the only way known to increase the temperature of a Bessemer blow if said blow be too cold from any cause.

X Q. 65. With reference to the melting of scrap and pig iron in the cupolas to which you have referred in answer to question
538 41, was it not a fact that the cupola fans did not work satisfactorily and that the cupola melted slowly, thereby making a high sulphur metal, which would have been undesirable to charge directly into the converter?

A. I have no recollection of a sulphur content of this metal, but it is a fact that the cupola fans, and I think also the hoist, were not satisfactory and prevented these cupolas from melting as fast as they could under proper conditions. I should be inclined to think, however, from my knowledge of some of the off metal that went into these cupolas, that the percentage of sulphur in the molten metal would be always high.

X Q. 66. And would such high sulphur metal have been fit for making good steel rails unless it were first poured into the mixer or mingled with the mixer metal?

A. High sulphur is a comparative expression, and when I used it I was thinking of metal that would run from seven-hundredths per cent. to one-tenth of one per cent. This metal could be converted into steel if its other constituents were proper, as they probably were, and the resulting product would not differ very much in sulphur from quite a good deal of Bessemer steel that has been made. Steel rails made of such molten pig iron would be equal in quality to ones containing lower sulphur, and I think would be called good.

X Q. 67. Do you wish to be understood as meaning that their

quality would be better if such cast iron were poured into mixer instead of taking directly into converter?

A. The average sulphur contents of Edgar Thomson molten metal is, I suppose, in the neighborhood of two or three hundredths of a per cent., and if this metal containing a higher percentage of sulphur was passed through the mixer, its percentage of sulphur would undoubtedly be reduced so as to come somewhere nearer to the average of the metal in the mixer, but I do not believe that the resulting rails would be any better.

539 X Q. 68. During your first employment at the Edgar Thomson, prior to the use of the mixer, was it the practice to roll the blooms direct without reheating?

A. No, they were reheated; the ingots being heated, were rolled into blooms. The blooms were then reheated and rolled into rails.

Redirect examination by Mr. KAY:

Q. 69. During your second employment at the Edgar Thomson works, how long a time was required to make analysis for silicon after the metal was taken from the ladle?

A. The actual determination can be made in less than 11 minutes. I suppose that the average time would be from 15 to 20 minutes.

Q. 70. That being the average time from the taking of the sample to the delivering of the result to the blowers or scrapper?

A. I don't know whether that was the average time, but it can be done in that time.

Q. 71. How much time would ordinarily be required after the sample was taken from the ladle to introduce that ladle full into the converter, blow and pour it, and introduce the next ladle full into the converter.

A. A very fair average of that time would be 26 minutes.

Q. 72. I understand from your testimony that two ladles full of metal would be withdrawn from the mixer and these two ladles be drawn by the locomotive to the converter-house and sample taken from the first and analyzed. Was that the regular custom?

Objected to as leading.

A. That is my recollection of the regular practice.

Q. 73. Which would have given the analysis quicker, the taking of the sample from the ladle at the mixer and sending it by
540 special messenger to the lab-ratory, or the taking of the sample from the ladle after it reached the converter-house?

A. I think there would be very little difference in time. If anything, when the mill is working regularly, if there is any advantage, it would be in favor of taking the sample at the converting mill, as is now done.

J. S. ROBESON.

Examination of Jos. Morgan, Jr.

Q. 1. What is your name, age, residence and occupation?

A. Jos. Morgan, Jr.; 54 years of age; residence, Johnstown, Pa.; occupation, chief engineer of the Cambria Iron Company.

Q. 2. What experience have you had as a mechanical engineer in connection with the manufacture of iron and steel, and what education have you had?

A. Have had 35 years of professional experience in engineering, 31 of this at iron works and 18 of it at a large works making finished material from the ore up, and for 15 years have been in responsible charge of an important department of same. I am familiar with the art of steel-making, its progress and history, from the date of the invention of the Bessemer process to the present time.

I was educated at Central high school, Philadelphia, from which I entered the steam-engineering corps of the regular navy in October, 1861, in my nineteenth year. I received mention in official reports for service done in the sloop-of-war "Brooklyn," at New Orleans, under Farragut, in April, 1862. I received the degree of A. B. in July, 1862, by special vote of the faculty of the Central high school, and subsequently that of A. M. I was promoted to second assistant in 1863; resigned from navy in January, 1866, after the war was over, after four years of active service, and
541 entered the employment of the Phœnix Iron Company, at Phœnixville, Pa., as draughtsman, becoming chief draughtsman in 1868.

Afterwards I was ten years with the Edgemoor Iron Co., near Wilmington, Del., as chief engineer. As such I served upon the board of engineers to assist Civil Engineers Linville, Clarke and Chanute to report upon the character of structure to be built for what is now the Manhattan Elevated railway. I went to Cambria iron works in 1879 as draughtsman, and was made chief engineer in 1881. I designed and superintended rebuilding of various parts of works, including six blast furnaces, new Bessemer works of largest class, new blooming mill, open-hearth plant, rail mills, and various large mills of Gautier plant, involving expenditure of millions of dollars and quadrupling the productive capacity of the works. I am a member of the American Society of Mechanical Engineers, American Institute of Mining Engineers, and U. S. Naval Institute. I was abroad in 1884 to examine the subject of gun and armor forging, and visited principal English and Continental works. I was appointed a member of the United States fortification board in 1887 and aided in making reports. Other members were Mr. Endicott, Secretary of War; Generals Newton, Benet and Abbott, and Captain Smith, of army; Captains Samson and Goodrich, of navy, and Erastus Corning, of New York. I have written several papers to aid in forming correct public and congressional opinion on the subject, and my confidence expressed in future development of steel guns and armor manufacture, then in the infancy of the art, had been amply verified by results since obtained.

Q. 3. Have you carefully examined the different patents and publications which have been offered in evidence, as well as the testimony of the different witnesses, both for complainants and defendants, taken in so far as they illustrate the history of foundry and

Bessemer practices, and if so, do you understand the different methods described as practiced in this country?

542 A. Yes, I have examined the patents and publications and have read the testimony already in the case several times.

Q. 4. Have you examined the letters patent to Wm. R. Jones, sued upon in this action and known as the Jones method patent, and if so, please state what you as an engineer understand the invention set forth therein to be?

A. I have carefully examined and studied the patent at many different times. It is entitled a "Method of mixing molten pig metal." I understand the words "pig metal" as used here to mean the crude iron produced by blast or smelting furnaces, which is the raw material used in various processes of refining iron, for making castings and other uses in the art. The term "molten pig metal" includes metal taken from a blast furnace direct in a molten state, or such metal remelted in a cupola or air furnace, or in any way possible in which crude pig metal can be melted. "Molten metal" to metal-urgists means the liquid form of any metal that will liquify. In this patent "the method of mixing molten pig metal" is for the purpose of obtaining so good an average of molten pig metal as is necessary preliminary to a refining process or for other uses in the art. Methods of mixing pig metal prior to remelting, have long been known in foundries and from the beginning of the Bessemer refining process. This old method of mixing solid metals is to add such units together as when melted and mixed will give the average pig metal desired. The mixture occurs after melting. The method of mixing molten metals in the patent under consideration is to add such molten units together as will give the average desired. This is distinctly a mechanical operation, the average being determined by arithmetical methods, no chemical reactions necessarily taking place. The units added together when molten will give the same results as if added together solid and when melted with proper allowance for oxidation in the melting process.

543 Mixing of molten metals is called by the plaintiff, in his testimony, the mixer process. As an engineer, I consider this process a simple operation long known in the art, which begins with melted metal and ends when the mixture is obtained. The specification says: "In practice it is found that metal tapped from the different blast furnaces is apt to vary considerably in chemical composition." This is well known, and therefore in the mixing-reservoir practice the various charges are mingled together in a molten condition to obtain an average, while in the cupola practice of mixing the various charges are either mingled together when solid and are then melted or are melted and allowed to mingle afterward in a reservoir. This is a brief statement of the essentials of the two methods of mixing. It is necessary in both methods of mixing that such units shall be mingled together as will give the desired average. Neither method necessarily adds any constituents or takes any constituents away from the pig metal. Hence in Bessemer practice very high or very low silicon heats or higher silicon heats

or high sulphur heats are generally rejected or laid aside in cupola practice, and they are often rejected when coming from the blast furnace in the melted mixing practice as off-heats.

With cupolas in American Bessemer works it has long been the practice to dump various heats or taps from the blast furnaces into the cupolas indiscriminately and about as they come from the furnaces in regular sequence, this being the necessary mode of procedure in rapid cupola driving, there being practically no time for the selection of special heats. The mixture is either obtained incidentally in passing through the hearth of the cupolas or finally in the reservoir or mixing ladle into which the various cupolas are tapped in sequence or simultaneously, as desired. In the reservoir practice the same method must necessarily be used, as taps are taken in order about as they come while fluid. Ladles containing different heats from different furnaces can be alter-ated with each other and a mixture of heat obtained, or portions of taps can alternate with each other and mix in the cupolas. The averaging
544 methods are similar, the only difference being in the physical condition of the metals mixed.

The Jones patent covers a method of mixing a "charge composed not merely of metal taken at one time from the smelting furnace, but a number of parts taken from different smelting furnaces or from the same furnace at different cast or at different periods of the same cast," which charge is subjected "to a process of mixing whereby its particles are diffused and mingled thoroughly among each other, and the entire charge is said to be practically homogeneous."

The broadest specification of the method of mixing says that the "invention may be practiced by merely receiving in a charging ladle a number of small portions of metal taken from several ladles or receiving vessels containing crude metal obtained at different times or from different furnaces, the mixing being performed merely by the act of pouring into the charging ladle, and other like means may be employed." The apparatus is not claimed in the patent and it will be seen that "an ordinary charging ladle" may be used as the simplest form of apparatus, and it is also stated that the invention may be practiced with a variety of forms of apparatus.

The method of feeding the several portions of metal into the mixing apparatus is not material, as results must be the same whether the mixing apparatus receives its several additions by ladles or by runners from several blast furnaces or from the runner at different times in the same tap of a blast furnace and the same operation may be performed with metal from cupolas or from melting furnaces.

It will be seen from the broad statement above quoted that the process may be carried out in a fixed vessel before any motion is given to the vessel or without any stirring. As an engineer, I know that mixing will result from pouring dissimilar metals into a fixed vessel.

In the Jones specification it is stated that "the invention is not

limited to its use in connection with converters since similar
545 advantages may be obtained by casting the metal from the mixing vessel into pigs for use in converters, puddling furnaces, or for any other use to which pig iron may be put in the art." From this I understand the patent to cover the use of the mixer or receiver in a foundry to prepare metal for casting.

The first claim is for a method of mixing molten pig metal "in the refining of iron directly from the smelting furnace." Metals were refined directly from the smelting furnace from the beginning of Bessemer work and pig irons were mixed in refining operations directly from the smelting furnace for a long period prior to the patent in suit, and therefore I consider that the invention must be found wholly in a new method of mixing pig metal. Pig metal is a well-known material. Mixing pig metals in the Bessemer process were well known.

Examining the first claim for a disclosure of the actual method covered I find it to be the "process of equalizing the chemical composition of the crude metal by thoroughly commingling and mixing together the liquid metal charge." The language of claim as to the method is so vague that it cannot be said to disclose a method. It would be carried out when blast is turned on a converter in the ordinary way. From the specification I find it may be practiced in an ordinary charging ladle by merely pouring into it different portions, as was practiced at Terre Noire and many other places long prior to the date of the patent in suit.

The second claim differs from the first in that it says "mixing molten metal," by which latter term all liquid cast iron is designated whether from blast furnaces, cupolas or air furnaces. Further the claim omits all reference to refining processes, broadening the method to take in any molten metal and any other use to which the mixed pig iron may be subsequently put in the art. The method itself is narrowed to a mixing of different portions of molten metal, and pouring out part thereof without entirely draining the receptacle and then adding metal to what is left.
546 The second claim defines only the method of mixing molten metal without any allusion to blast furnaces on the one side or refining process on the other. Broadly characterized, the claim describes the common, usual and inevitable method in which molten metal has been stored and handled from 1865 in all American Bessemer works and in American car-wheel foundries for a still longer time.

Q. 5. Will you please give a history of the methods of mixing as practiced prior to the date of the Jones method in controversy, in foundries for casting iron and steel, and illustrate by a few examples from testimony, stating at the same time the bearing of such practice upon the Jones patent in controversy?

A. One of the oldest and simplest methods of mixing practiced in foundries is to maintain in front of a single cupola a large ladle into which the various taps from the cupola are run as they are melted down, in which ladle they are commingled and diffused, and by which an average produce of melted iron is obtained; the

smaller ladles or shanks (so called) are filled from this large reservoir as desired for making small castings, and the large ladle is filled from time to time with additional taps. This is a method of operation precisely similar to the method described in Jones' second claim. This is ordinary foundry practice and is in evidence in the testimony of Mr. Cupples as to practice in making shell in the Fort Pitt foundry. This is also in evidence in Kirk on "Founding of Metals," published in Sharon in 1877, who says:

"A quantity of molten iron should be kept in the cupola or in a large ladle, so as to give the different brands of iron a chance to mix. In most all the foundries at Wheeling, W. Va., the cupolas are never stopped in from the *the* time the blast is put on until the bottom is dropped. A large ladle is set on trestles in front of the cupola in such a manner that the iron can run into it from the cupola and be poured out into the smaller ladles at the same time.

547 The iron is all run out of the cupola as fast as it is melted, and is mixed in the large ladle. I think this is a good way of mixing irons."

I consider this embraces and discloses the method of the Jones patent.

A further example of mixing is found in the Fort Pitt practice in bringing together the heats of two or three air furnaces in a common reservoir and tapping them into molds for guns. Several instances of this can be found in the "Reports of Officers of the Ordnance Department," United States Army, published in Philadelphia in 1856. The first one, page 169, gives the details of the manufacture of two 8-inch columbiads at Fort Pitt works, August 4, 1849. Two cannons were cast at one time from the same iron. Another report states:

"The iron for both castings was melted at the same time in the two air furnaces, each containing 14,000 pounds same kind of iron after melting, the liquid iron remained in the furnace one hour exposed to high heat and was then discharged by separate streams into a common reservoir. From the reservoir it is issued in a single stream which, after proceeding a few feet, separated into two branches, each leading to a separate mold. Both molds were filled at the same time."

A similar example is given on page 184 of the same works of the casting of two 8-inch columbiads, July 30, 1851. Iron was melted in two furnaces, which were discharged by separate streams into a common reservoir at the same time and was withdrawn from reservoir in a single stream. A similar example is given on page 185, same work, of the casting of two 10-inch columbiads, August 21, 1851, where iron was melted in three furnaces, which were discharged at the same time into a common reservoir, from which melted iron issued in a single stream. These examples may be multiplied.

In "Reports of Experiments on Properties of Metals for Cannon," by Captain Rodman, of the Ordnance Department, published

548 in Boston, in 1861, and referring to the two guns made in a similar manner, on page 129, Captain Rodman says:

"The iron of which these guns were made entered the gun molds identical in quality, the molds being simultaneously filled from the same pool of melted iron."

The same method of making gun castings is also described in testimony of witnesses Cupples and Frew. From above quotations I conclude that this method of mixing metals was recognized by Captain Rodman as one of the equalizing or commingling the product of two or three furnaces. This embodies the method of mixing of the first claim and approaches closely to the second.

We have also the mixing receptacle of the second claim filled with successive portion- of metal from several furnaces; we have portions of its composite molten contents being removed from the vessel at the same time, and we have the successive replenishing operation mixing with the metal in the receptacle, the only difference being that it is a continuous instead of an interrupted process.

When we reach the date of 1853 we find in evidence the practice of the Whitney car-wheel works, which have been in operation from that date to this. In these works we have testimony as to three melting cupolas tapping at intervals into a large reservoir ladle of 15-tons capacity, in which ladle different taps from the cupola are mingled with each other and with taps from other cupolas, and from which smaller ladles of about 600 pounds each were filled from time to time. The Altoona foundry of the Pennsylvania railroad is also in evidence with an apparatus constructed in 1873, consisting of two cupolas and a mixing ladle, with similar practice to that of the Whitney foundry. This Altoona foundry, as the property of the Pennsylvania railroad, is widely known and was illustrated and described in the London Engineering of 1877, vol. 23, page 357; also in Sperton's work on "Casting and Founding," published in 1880. In this description it is said:

549 "It was found advisable to employ a ladle of so large a capacity because by doing so a more complete mixture of different irons is effected than would be the case if a smaller vessel were employed."

The details and manner of carrying out the method at the Whitney and Pennsylvania car-wheel foundries meet the details of the method as described in the second claim. As a practical man I would say that the second claim exactly and minutely describes the method of the wheel foundry in question.

Illustrating the knowledge of methods of mixing metals, we also refer to the notes on Construction of Ordnance, No. 21, Washington, May 14, 1883; Fabrication of Cannon in Russia, page 14, describing the method of casting large cannon, such as 12 inch cannon, which weigh more than 25,800 pounds, etc.

"Steel from the crucibles is run at first into a pool, from whence it afterwards flows in a continual stream into the mold."

All practical men know ingots for ordnance forging should be as uniform as possible in structure, and this reference illustrates the method for obtaining an ingot of uniform average material from a number of small sources of supply. It illustrates and embodies the method of mixing of the first claim.

It is also in evidence that long prior to the Jones invention it was the custom of the Fulton foundry of Totten & Company in making large castings to melt part of the metal in a large air furnace and the remainder in a cupola furnace, and to tap the metal from these two furnaces into a large ladle, by which the mixture of the two metals was obtained and then it was poured into the mold. This, I believe, embodies the method of the first claim.

Q. 6. Please give a brief history of the manufacture of Bessemer steel as disclosed in patents or publications in evidence, and
550 show the state of the art in regard to use of direct metals, ladles, and reservoirs at Bessemer works, confining yourself to European operations and carrying it up to 1882, the date of the South Chicago direct works.

A. The Bessemer process of refining crude pig iron was invented and developed in the years 1855 to 1859 as described by Sir Henry Bessemer in his Cheltenham paper referred to in Kohn Iron & Steel Manufacture. Mr. Bessemer proposed to tap the fluid crude iron from blast furnaces directly into the converting vessel. This process was probably first successfully and commercially carried out by Goransson, of Gefle, Sweden, 1858. Mr. Goransson made Bessemer steel directly from the blast furnace, and the Swedish works have from that day to this made steel of high grades directly and successfully from the blast furnace. In fact, Swedish Bessemer works have been erected only at blast furnaces and work by direct method, as stated in Kohn, published in 1869, page 74, now in evidence. The earliest recorded instance I have found of carrying metal from blast furnace to converter in a ladle is that of Neuberg, Austria, mentioned in Kohn, page 95, now in evidence, where two blast furnaces furnished molten metal for two 3-ton converters. The metal is conveyed from furnaces to converters by a ladle mounted upon a truck.

At the Terre Noire works ladles were fil-ed at blast furnaces and run to converters at least as early as 1867, as illustrated by French patent of that date.

Bessemer's English patent 566 of 1869 disclosed an intermediate reservoir whose office was to receive and measure heats between cupolas and converters.

The earlier Bessemer works in England were not generally erected at or near blast furnaces; among these were H. Bessemer & Co., John Brown & Co., of Sheffield, and Penistone works, of Chas. Cammell & Co. The profits of earlier Bessemer works were very large. The Henry Bessemer Co. were said to have divided 81 times their capital in 14 years. Hence there was at first no great in-
551 centive to cope with the development of the practice of direct work. Barrow was apparently the first English works designated for using metal direct, and Kohn, page 82, describes use of ladles there to carry iron from furnaces to converters. The first recorded example of mixing direct metal in evidence is that of Terre Noire, spoken — by Mr. Kohn in the Journal of the Iron and Steel Institute, 1871:

"The iron is first run into a ladle, as explained by Mr. Menelaus,

and so taken to the converter. The ladle is brought to the back of one furnace and half filled; it is then run to the next furnace and filled up. In this way the Terre Noire Company always obtain a mixture of metals, and therefore the greatest regularity is secured through the rest of the work."

The description embodies and discloses fully the whole of Jones' first claim, as limited to refining process and to molten metal direct from blast furnaces at Creusot, France, they are working direct in 1871 according to Kohn, carrying the metal in ladles to converters.

In 1872 a patent was taken out in England by Mr. Abel for Z. S. Durfee, of New York, which is the blending of the substance of the U. S. patents take- out by Durfee in 1871. In the provisional specification it is entitled, "Improvements in the manufacture of Bessemer steel and iron, and in the production of iron castings and in apparatus therefor."

Abel states:

"Between the smelting furnace (whether a blast furnace or a cupola furnace) is introduced a reverberatory mixing furnace, by preference a gas furnace, of any suitable known construction, into which the crude metal from the smelting furnace is run, and wherein it is mixed with pig iron of suitable qualities or with iron or steel or metalloids, such as it may be desirable to alloy with the crude metal," * * * "and the usual tests as to quality being applied to mixed metal. The metal thus treated is then run into the converting vessels." * * * "Also the metal supplied for
552 alloy in the mixing furnace may be poured or run into it in a liquid state from the melting furnaces or cupolas situated near it."

It is further stated that the method may also be used for giving the desired quality and character of iron to be used in making castings. The specification of September, 1872, has a similar title, and recites the advantages and difficulties of direct use of blast-furnace metal in the Bessemer process as fully and clearly as the Jones specifications do. Durfee proposes to secure the greater part of the saving due to the use of direct metal, but does not claim to save all of the expense of running cupolas and remelting the pig iron. He proposes to "mix irons to any desired extent" in a large furnace or furnaces or in—

"A reverberatory furnace, by preference a gas furnace, into which furnace the crude iron as it is brought from the blast furnaces may be poured, and wherein it may be mixed with other irons, and be so treated as to insure the metal from time to time tapped out for conversion being as nearly as practicable of a uniform character. So many and so large furnaces may be used as the work in process may demand; but in many cases one furnace of about double the capacity of the converter in use will be sufficient, as the necessary correction of the character of the crude iron can be quickly made."

In the Abel-Durfee English patent I find a disclosure of the Jones method, and am of the opinion that Jones' apparatus, when heated with gas as described by him, is to all intents and purposes a reser-

voir furnace. The Durfee apparatus is practically a roofed reservoir as well as a furnace.

In 1873, Mr. Deighton, of Workington, West Cumberland, England, a roll-turner, draughtsman and designer, took out English patent 3672, for "Improvements in arrangements and mode of working apparatus for the manufacture of Bessemer steel," which proposed certain changes in the then type of Bessemer plant, all of which I recognize as advances in the art of that day. Among other things, Deighton proposed making steel from pig metal direct from blast furnaces. He says:

553 "Instead of manufacturing Bessemer iron or steel from pig iron, which has to be remelted in the cupolas, my invention also consists in taking the molten metal directly from the blast furnace to the converter, in which case I prefer to arrange the Bessemer plant in a line at a right angle to a row of two or more blast furnaces, and place a vessel to receive the molten metal tapped from two or more blast furnaces to get a better average of the metal, which will be more suitable for making Bessemer steel or metal of uniform quality, the vessel or receiver being placed on a weighing machine so that the required weight may be drawn or tapped from it and charged into the converter."

He illustrates his method by drawings, "showing my improved arrangement of plant for manufacturing Bessemer metal directly from the smelting furnace." He shows smelting furnaces with gates or channels to convey molten metal from each of four furnaces, which channels lead to a receiving vessel which is placed low enough to give fall for the molten metal to flow from the blast furnaces to the receiver, which forms a receptacle for mixing the molten metal from two or more of the smelting furnaces. From the receiver the mixed molten metal is tapped and flows down the swivel through into the converter. The mixing vessel is placed on a weighing machine by which it can be readily ascertained when the exact quantity has been tapped into converter.

Among his claims are:

"Fifthly. The system or mode of arranging and working Bessemer plant in connection with one, two or more blast or smelting furnaces, substantially as hereinbefore described and illustrated by Figs. 4 and 5 of the drawings.

Sixthly. The system or mode of arranging and working Bessemer converters with a receiver or receptacle (*m*) for mixing the molten metal from two or more smelting furnaces to get a more uniform quality of metal, substantially as hereinbefore described and illustrated by the drawings."

554 As a practical man, I would say that this patent discloses fully and completely the Jones method, as the apparatus shown was intended for mixing the metal from two or more blast furnaces, and in the hands of any one skilled in the art must and would, inevitably, have been used as described in the Jones method patent.

It is evident that this vessel is described as receiving the metal from two or more blast furnaces for the purpose of mixing it. The

drawing shows a vessel of sufficient size to receive the ordinary taps for several furnaces at once, to store them for a time, and it provides means for storage and tapping converter heats out in measured quantities, as desired for use in converter, which certainly means that metal would remain in the receiver after this measured charge was withdrawn, into which in the normal use of such a receiver the molten metal from one or more of the blast furnaces would be tapped. As used by a practical man, it would be filled by successive taps from the furnaces, which in ordinary course of working would be ununiform in their non-metallic constituents. Portions only of the contents of the receptacle would be taken to the converter without emptying or draining same, and it would be successively replenished with ununiform additions, which would be necessary in continuous working of the blast furnaces and converting works.

A careful examination of the patent drawings leads to the conclusion that they are on a scale of about $\frac{1}{8}$ inch to the foot. This harmonizes the details of the drawing and makes the railroad shown on drawing 4 feet 8½ inches gauge, or standard, and makes the converters about 8′ 6″ in diameter, or the usual size of a 5-ton converter, the size most in use at that date. This makes the mixing receptacle about 9 feet inside diameter and about 7 feet high, and it would hold over 100 tons of molten metal. This is over 20 heats of the converter shown on the drawing, and probably equal to one-half of the daily product of four blast furnaces of the size in use at that day, blast furnaces at that time rarely produc-
555 ing more than 50 tons each per day in the West Cumberland district.

As an engineer, I would say that this was a liberal amount of storage, both to accomplish mixing and to provide for emergencies in working blast furnaces or converters.

The Jones apparatus of two mixers at Edgar Thomson works holds about 150 tons, or from one-eighth to one-twelfth of a day's work of the converting works and about three taps of 50 tons each from the blast furnaces, as testified to by complainant's witnesses. The patent of Mr. Deighton discloses an apparatus which can be practically worked and which would inevitably be used in the method described in the Jones patent.

In 1874, at the meeting of the Iron and Steel Institute of Great Britain, a discussion of Holley's paper on "American rolling mills," was according to Holley's own language in his report of 1877—

"Allowed by Mr. Bell, then president, to drift into one of the most important and fruitful interchanges of opinion, not only about the direct process, but about its advocates and its opponents which ever occurred in England or elsewhere."

In this discussion the saving of cost of cupola remelting by working direct was fully recognized by Messrs. Williams, Ramsden, Richards, Snelus, Smith and others. It was the general consensus of opinion that while this was attended with difficulty, with experience they could overcome the difficulties. Mr. Snelus said among other things:

"But the first essential was to get the metal sufficiently silicious to blow well, and by running it into a separate vessel, as they did in America, they could then deal with it as they liked. The plan in all the works in America was to melt in a cupola continuously, and then to run the iron into a ladle which was balanced and held from 10 to 12 tons. From that the 6-ton charge was run direct into the converter. They wanted an intermediate vessel between the blast furnace and the converter * * *."

556 In this last sentence I find a particular disclosure of the real trouble in working direct and the method of remedying it. A suggestion to use the American reservoir ladle brings us to a practice that embodies the method of the Jones patent. In the English method of cupola working without an intermediate ladle there is no accurate means of measuring converter heats. When the metal is brought direct from the blast furnaces in charging ladles, the sizes of the heats carried to the converters are still more variable. A reservoir allows accurate heat-measuring, and when it is used in the American method of constantly refilling with fresh additions, &c., from several cupola furnaces, and Mr. Snelus suggests its use between the blast furnace and the converters, it gives the mixing method as disclosed in the Jones patent. With this disclosure nothing is left the engineer to devise but an apparatus of proper size and construction.

In 1874, immediately after the discussion at the Iron and Steel Institute meeting, in which Snelus made the suggestion of reservoir ladle as used in America, to receive direct metal or store it, Mr. Z. S. Durfee wrote to London Engineering calling attention to his plan for accomplishing mixing:

"I propose to erect at some convenient place as near as possible to the converters, one or more gas reverberatory furnaces of sufficient size to hold the average tap of the blast furnaces supplying the metal for conversions, and then run or pour the crude metal from the blast furnaces into these gas furnaces, where it could be alloyed or treated as desired, and thence be tapped out from time to time as required for the converting operations * * *

"Indeed, all conversant with the Bessemer process and the mixing and melting of pig irons will, I think, see that a reasonable supply of suitable iron for mixtures and with the facilities for treatment arising out of the manageableness of gas furnaces, a continuously good average standard of iron for conversions can be maintained on my plan from one year's end to another. * * *

557 There should be no difficulty in adopting my plan even to existing works, will be seen from the following facts: 'The quantity of iron now converted at once in Bessemer works is so large that even after it has been tapped out into a ladle, or run into the converter, it may be retained in a sufficiently hot and fluid state for the converting process for a long time, and I have known it to be so kept for several hours.'"

I regard the Durfee letter, which is a reiteration of the plan proposed in his English and American patents, as a disclosure of the Jones method.

In 1875, at a meeting of the Iron and Steel Institute, the subject of direct metal was again discussed. The history of the art was briefly given by Mr. Deby, of Belgium.

In 1876, the subject was again discussed at both the spring and fall meeting of the Iron and Steel Institute of Great Britain.

Messrs. Smith and Barrow; Richards, of Ebbw Vale, and Snelus, of West Cumberland, describe their success in working metal direct. Mr. Snelus said:

"There was one point that had not been mentioned; with all the care that could be exercised at the blast furnace he did not think it was advisable to take the iron from one furnace, but they might get an average mixture by taking it from two. They found no difficulty in taking three tons from one furnace, stopping the furnace up again, and then going to another."

In this quotation of Mr. Snelus I find a disclosure of the mode of mixing of the Jones patent, particularly the first claim.

Mr. Bessemer said: "The earliest idea he himself had ever entertained of the converting process was by the employment of molten metal direct from the blast furnace, and it was only because that he had not access to a blast furnace in his first experiments that those experiments were made with remelted pig iron." He must say * * * that "he was exceedingly gratified to see that it was quite practical to work iron successfully by his process direct from the blast furnace; he had, himself, proposed the tapping of three furnaces into one ladle or receiver, and when he advised some
558 of his friends, in a company with which he was connected in the neighborhood of Barrow, to go into steel-making, they arranged their works some two years ago, so that the pig iron could be tapped into a ladle or rather into a spherical vessel with an almost closed top to it, that would hold 20 tons. It was proposed to take at least three 7-ton tappings into that vessel, and to move it on wheels into the converting-house, using a pair of converting vessels one after the other, until the four charges of 5 tons each were worked off; having a second ladle or vessel on its journey to supply, so as to keep on working continuously and thus retain the heat and form no scull at all in the ladle during transit." * * *

In the suggestion of Mr. Bessemer of a mixer vessel on wheels, receiving taps of three furnaces into one vessel, taking his vessel to converter-house and working off successive charges from it, I find he discloses the method of the Jones patent.

In the language of Mr. Holley, in his report of 1877, referring to this meeting of the institute in the spring of 1876:

"So soon as the March meeting in 1876, Mr. J. T. Smith of Barrow, who had previously intimated that the direct process could not be successfully carried out in England, frankly acknowledged that he had been laboring under an error, and he proceeded to tell what he had already accomplished in this direction at Barrow. Meanwhile, or shortly after the West Cumberland, the Dowlais, and the Ebbw Vale works had introduced the direct process, and they have all been carrying it out with some degree of success, and also with improvement ever since."

At the fall meeting of the Iron and Steel Institute in Great Britain in the same year, 1876, the subject was again discussed, Mr. Snelus describing in detail his method of mixing iron from two or more furnaces, again disclosing the method of mixing of the Jones patent.

In the Iron and Steel Institute Journal of 1878 I find in the
559 discussion of Mr. Holland's paper the subject of direct working of Bessemer plants again comes up and Mr. Snelus said:

"Because he had himself been in correspondence with Mr. Holley, who had informed him that at Bethlehem works Mr. Fritz was doing half their work direct from the blast furnace, and had for some time had under consideration the idea of a receiving ladle, so as to receive the metal from the blast furnace and hold it in readiness there for the converters. One great drawback to the direct casting process was, that you could not always get your metal at the exact time you wanted it. He believed that it would be found that the great advantage the Bessemer works in America had was the intermediate receiving ladle which was designed by Mr. Holley, and which was universally used there, although it was never used in England. The Moss Bay Company attempted to modify the thing some time ago, and put up a heating furnace, but that, to his mind, was a step in the wrong direction. Anyhow, the thing had failed, and no one in England, as far as he knew, was using any intermediate receiver between the blast furnace and the converters. He thought himself that the receiver was of considerable importance, both for saving time and for facilitating the admixture of iron; and he was confirmed in that view by the idea of Mr. Fritz, of Bethlehem, who was about putting up a 30-ton ladle according to Mr. Holley, to receive the metal from the blast furnace, and hold it in readiness, so that at a moment's notice you could take your iron into the converter and also obtain a better mixture."

In this quotation from Mr. Snelus I find again urged the use of an intermediate vessel or receiving ladle as used in American plants, interposed between the blast furnaces and the converters, instead of between cupolas and converters. The advantages suggested are the storage to enable the works to have metal at the exact time it is wanted, the saving of time and admixture of iron. As an engineer, I consider this a complete and full disclosure of the entire method of the Jones patent. I also find in the suggestion of Mr. Fritz in the size of the apparatus a noteworthy increase over the cupola
560 storage ladle, sufficiently great to adapt the apparatus to blast-furnace direct metal, considering the plants as used at that date and their production.

In 1880, we find in "Jean's History of Steel," published in London, and universally accepted as showing the state of the art at or before that date, a quotation from Laybourne's paper, read 1877–1878, before South Wales Institute of Mining Engineers, a description of the Rhymney works:

"More uniform results being obtained by mixing the product of two or more blast furnaces, this plan is followed here, with the means of taking a further supply of iron when required from the

cupolas (two in number), which are situated alongside the subway leading from the furnaces to the steel works."

The description is accompanied by a plan showing the works. Mr. David Evans, a witness for the plaintiff, was general manager of these works from 1873 to 1885. As an engineer, I find in the description a disclosure of the Jones method of mixing.

In the London Engineering, volume XXX, 1880, I find in a description of the Barrow works, and its provisions for using direct metal, these words:

"If desired, the whole charge may not be taken from one furnace alone, but a mixture of the product of different furnaces may be made."

As an engineer, I find in this a disclosure of the Jones method.

Mr. David Evans was also general manager of these works from 1885 to 1891.

With this last quotation regarding English practice, we bring the art of England to about the date of the first use of direct metal at the Edgar Thomson and South Chicago.

Q. 7. Give a similar history of the manufacture of Bessemer steel in the United States, illustrating it by patents and publications of American origin, and show the state of the art in regard to
561 the use of direct metal, ladles and reservoirs in this country up to the date of the patent in suit?

A. American Bessemer practice commenced at Wyandotte and Troy. At Wyandotte the original practice was with metal direct from the blast furnace, conveyed from furnace to converter in a ladle, under the superintendence of Mr. Wm. F. Durfee, who made the first Bessemer steel produced in this country in 1864. A. L. Holley, who built the Troy works, and made his first conversion in 1865, introduced into this original plant tipping accumulating ladle resting on scales. This ladle was patented by Bessemer in 1869, English patent 566, alluded to in the previous answer but apparently was an American invention. It was introduced in some form or other in all the American works, and was used almost always in duplicate, holding about two heats each, or many cupola tappings. In the last works built at St. Louis by Holley, in 1876, there were three of these ladles. In all American works these ladles were turning or tipping ladles and were placed on scales to weigh the converter charges.

Thus Holley did for the receiving ladle of the Bessemer 1869 patent, which was fixed, what Jones did for the Deighton receiver, namely, made it a tipping reservoir. Early American steel works commencing with Troy in 1864, Pennsylvania in 1867, Cleveland in 1868, Cambria and Union in 1871, North Chicago in 1872, Joliet and Bethlehem in 1873, Edgar Thomson and Lackawanna in 1875 and Vulcan in 1876, used receiving ladles, two in number, holding about two heats each, with the exception of Bethlehem, which used a single ladle on a car to mix taps from four cupolas, and Vulcan, which used three receiving ladles, holding two heats each. These ladles were used for storing and measuring the heats.

In 1871 Mr. Z. S. Durfee was granted two patents for "improve-

ment in the manufacture of iron and steel," and "Improve-
562 ment in method of making iron and steel castings." The substance of these patents has already been alluded to in discussion of the Abel-Durfee (English) patent.

Durfee discloses fully the difficulty of using metal direct from the blast furnaces, and provides a practical way for mixing iron which, as an engineer, I regard as an disclosure of the method of the Jones patent.

In the London Engineering, vol. 15, February, 1873, we find an article by A. L. Holley on "Bessemer machinery" wherein he says of the cupola ladles: "Interposing ladles between the cupolas and vessels is important in many respects. First, the cupola cannot be so economically and regularly worked if its hearth has to fill up with the whole 12,000-lb charge every hour. Second, the weight of the charges would be somewhat uniform, to promote uniformity and accuracy of blowing and to recarburize with a fixed percentage of spiegeleisn. This can only be accomplished by weighing the charge between the cupola and the vessel, and the ladles are placed on scales for this purpose. Third, several charges are often run into the ladles when the converting department is not ready for them; otherwise the cupola would have to be dumped and part of the day's work lost."

In this quotation by Mr. Holley there is disclosed the functions of the Jones mixer, as the cupola ladles perform all the offices for the cupolas that the Jones mixer performs for the blast furnace, and the most important functions are recognized by Holley.

In an article by A. L. Holley, in the London Engineering, vol. 23, 1877, I find a description of the Vulcan works, the last plant designed and directed under Mr. Holley's supervision, from which I quote:

"In the melting department.—No American works is as yet using fluid iron direct from the blast furnace, although the Vulcan plant is arranged, and the others may be readily modified to do so. But in case the metal for conversion comes directly from the blast furnaces, the conveniences thus provided by the spiegel furnaces and for the vessels do not in the least interfere with the convenient
563 handling of the blast-furnace metal; on the contrary, this arrangement enables the convenient use of this metal in part and of the cupola metal in part, as may be made necessary by the insufficiency of smelting plant or by the irregularity of blast-furnace iron. If the intention is to use chiefly blast-furnace iron direct, the judicious use of the cupola (lined to a less diameter so as to run economically on a small product) enables the manager to mix and temper his irons, much sooner than he could do so by the blast furnace alone, and so to get a uniform steel."

"The cupola ladles *ff* facilitate the distribution of metal to the vessels. They form reservoirs which make the smelting department and the converting department independent of each other, within limits. This advantage was not appreciated fully until the large productions of the last few years were attempted, should any delay occur in casting, in preparing a vessel, or from any cause, the

melting department keeps right on, for those three ladles will hold six vessel charges, which may be stored and converted when the converting department is ready for them. Cast iron will 'live' in these thickly lined ladles, when covered with charcoal, for several hours. But it is necessary to put these ladles upon weighing machines, so that either uniform vessel charges may be run out, or so that spiegel charges may be proportioned to such charges as are run out."

In the description of the function of the middle ladle shown in the plans of the Vulcan works, I discover a disclosure of the method of the patent in suit, and also in the statement of the necessities of reservoirs to make the melting department and the converting department independent of each other, I find a full disclosure of the real functions of a large reservoir ladle in the direct process.

Bearing also upon the point of the functions of ladles in connection with cupolas, I refer to the proceedings of the American Institute of Mining Engineers, vol. 5, 1876, history of the Bessemer manufacture by R. W. Hunt, who describes the invention of Holley improving the Bessemer apparatus, saying, among other things:

564 "He substituted cupolas for reverberatory furnaces, and last, but by no means least, he introduced the intermediate or accumulating ladle, which is placed on scales, and thus insures accuracy of operation by rendering possible the weighing of each charge of melted iron before pouring it into the converter."

This reservoir ladle was variously named. Bessemer called it in his English patent, 566 of 1869, "A ladle or receiver," placed on a weighing machine. In Bessemer's patent it was fixed and to be tapped.

Holley calls them "cupola ladles," "interposed ladles," and "reservoirs." Hunt calls them "intermediate or accumulating ladles."

Thus we have cupola ladles described as "ladles," "reservoirs," "interposed ladles," "intermediate and accumulating ladles."

The purpose of reservoirs whether between the cupolas and converters, or between the furnaces and converters is practically this: They are regulating reservoirs between the operations of the melting and converting department to save heat and to equalize the temperature and the quality of irons poured into them, and to facilitate the correct weighing of heats.

Like the early English works, few of the American works had blast-furnace plants sufficient to supply the necessary pig metal for conversion. The profits were large, and hence none of the early works ran direct as a regular practice. Edgar Thomson works had no blast furnaces until about 1879, and for several years did not have enough blast furnaces to supply the pig. The new South Chicago works was the first plant equipped for direct use of blast-furnace metal from four new blast furnaces in 1882, and were closely followed by Edgar Thomson with their five new furnaces in the same year.

Both works discarded the American reservoir ladle and followed

the English in exact method of measuring heats by ladles
565 full, direct from furnaces, instead of weighing them—which practice increased the usual difficulties of direct work.

Mr. James P. Witherow, of Allegheny, took out two patents, one on April 14, 1885, No. 315,587, which provided a receptacle between the blast furnace and converter, capable of holding any desired quantity of metal, preferably holding the amount of a cast from blast furnace. It was, he states, "designed to inclose the vessel and maintain the heat of the metal, so as to keep it as long as necessary in the proper molten condition for tapping off into the converters, of which there may be several."

"Thus the vessel E constitutes an intermediate distributing reservoir for the metal after its withdrawal from the blast furnace, the use of which obviates the necessity of interfering with the regular and uniform operation of the blast furnace by the frequent tapping off of the relatively small quantity of metal necessary to charge the converter or converters, the time required for the operation in the latter being so short that they need to be charged several times between each regular tapping of the blast furnace."

As an engineer, I consider this discloses the method of the Jones patent, as the receiver would necessarily mix different portions of the same tap from a blast furnace, and under the natural practice, and unless care was taken to positively prevent, in case of variation of weight of heats from the furnace or to converter it would inevitably follow that portions of the different taps would be mingled together.

Witherow also patented in September, 1885, No. 327,425, another form of receiver, in which he covered several other requirements of a direct-metal reservoir by roofing it and providing means for maintaining heat, or adding to it by gas flames, and he also provided means for measuring consecutive converter heats. As an engineer, I consider the apparatus embodies many features of Jones' apparatus with which is practiced the method of the Jones
566 patent in suit, and that with the Witherow apparatus in use under blast-furnace practice, the method of the Jones patent must inevitably be practiced both in mixing different portions of same tap, it being well known that such metal is ununiform in quality, and of mixing different taps in case a remainder was left in reservoir, when it became necessary to again tap the furnace. The delays which are constantly occurring in the converter department, would make it practically impossible in the regular working of the plant to entirely drain the metal from the receiver before introducing another tap from the blast furnace: and as this receiver was intentionally provided for storage of the molten metal, and had tapping holes at different heights, I believe that to a skilled metallurgist this patent discloses the entire method of the Jones patent.

Q. 8. You have alluded to variation of weights of heats in handling ladles direct from blast furnaces to converters in English method of working without a reservoir. Explain how this happens and show

what trouble this occasions. Explain why a reservoir is necessary for weighing.

A. Ladles filled at blast furnaces with direct metal vary in weight for reasons well known to practical men, and especially at furnaces producing large quantities. Holley's '77 report gives the size of direct heat at Barrow as observed by him as varying from 4 to 8 tons. At Cambria works, in tapping at blast furnaces, the direct ladles are filled with quantities varying from 20,000 to 40,000 pounds of liquid metal. Mr. Forsyth testified to difficulty of some kind at South Chicago. Mr. Lauder in A. Q. 3 says as to direct ladles, "There was more or less difficulty from irregularity in weight of charge," and in A. X Q. 27, "There was no weighing apparatus attached to the ladles referred to. I cannot recall any other weighing than that of running it over a scale in order to keep a record of the amount of metal received from the blast furnace," and in A. X Q. 16, "My recollection is there was considerable trouble on
567 account of the irregularity in the amount of charges sent to the converter." My own observation of early Edgar Thomson direct practice showed a startling amount of scrap in shape of ingot butts, due to irregular weights of heats. This difficulty as to weight of furnace ladles arises from several causes:

First. There are generally no scales located at any of the furnace casting-houses to determine when each ladle has a definite supply. Weights are estimated by filling to a fixed height.

Second. If definite amounts are weighed in, indefinite portion of such weighed charge solidifies, according to the initial heat of the metal and the time it waits for conversion, making actual heats vary in size.

Third. Owing to large amounts of metal to be handled, difficulty with tapping holes and runners, it is hard to fill ladles with fixed quantities. They are over or under filled.

Several losses arise from difficulties which are avoided by use of reservoir, apart from any value it may have as a mixer:

First. Ladles standing waiting for conversion become sculled and part of metal has to be remelted. With a reservoir, ladles can be promptly emptied in minimum time.

Second. With irregular weights, short ingots or blooms not available for rolling to rails are made and become scrap and loss. This especially applies to rail practice. When making billets heat-weights are not so important. With reservoirs, ladles can be filled with heats of accurate weight for conversion, and with uniform heat-weight loss in rail-work is prevented.

Third. There is also difficulty with irregular weights in re-carburizing, necessitating more careful supervision or extra hands and a liability to error, giving irregular quality and a scrap
568 loss. This loss is especially felt in high-carbon steels, such as rails. This especially applies where heats are not weighed but estimated.

On the other hand, modern furnace practice has so increased the regularity of the iron output as to its chemistry that we should count upon blowing nine heats of every ten without much difficulty,

so far as heating elements are concerned, and with a far less loss from irregular quality of metal than from a practice which prevents accurate measurement of heats, so that for this use a reservoir might be dispensed with for much direct work.

From these considerations, as an engineer, I consider that the direct process today, for its regular working, depends much more for its success upon the storage reservoir and its further function of exactly measuring heats than upon the mixing incidental to storage.

Q. 9. Give a description of the method of using a reservoir or accumulating ladle in Cambria works where cupolas are used to furnish molten metal for the converter and show its similarities to or differences from the reservoir used for direct metal at same works. Show what determines the convenient size of reservoir for cupola and furnace molten metals.

A. A reservoir or accumulating ladle between cupolas and converters at Cambria works has been used and recognized as necessary since the first Bessemer steel was made in those works. In the beginning the Bessemer production was very small and there were considerably delays at the converters. One or two cupolas supplied all the iron that was converted, and the function of the ladle as an accumulator or for storage was very distinctly marked. As production was increased the cupolas were increased in number to supply the increased quantity of metal necessary, and about the same-size ladle answered all the storage requirements, while at the same time a larger number of furnace elements were flowing into the reservoir. As the converters were increased in size, from six to twelve ton heats, there was an in-
569 crease in storage ladle, not always in the same ratio, for the reason that old apparatus was continued in use where change was not absolutely necessary. In the beginning the cupolas were smaller and less productive than at present, but the ladles have always been sufficient to hold a number of taps, either of the same cupola, when one was used, or from five or six different cupolas as in present-day practice. This ladle has alway- been upon a scale to enable us to measure heats accurately. Describing the use of this accumulating ladle, we tap into it from the cupolas in succession or simultaneously a sufficient number of taps to fill it and pour out of it a converter heat when required, "not entirely draining or emptying the same." This follows from the large size of the ladle and from the fact that a definite-sized heat is poured out. The ladle is filled by fresh additions from the cupolas, thus keeping a supply ready for immediate use of converters. Incidentally this ladle has the advantage of mixing irons from different cupolas, equalizing their temperature and composition, so that the successive heats will work as uniformly as possible.

In devising a storage reservoir for blast-furnace metal we were obliged to take into consideration the very great productiveness of the blast furnaces of today. The iron from a furnace, even when tapped 6 or 8 times a day, amounts to about 50 tons at a tap, or as much as 300 or 400 tons a day from one furnace. A reservoir to

hold three or four taps must therefore be of sufficient size to take several hundred tons in order that the blast-furnace work and Bessemer work may proceed without interruption on the one hand by the furnaces waiting for empty ladles from the converting works or on the other hand by the converting works waiting for iron from the furnaces. The very large increase of size from Mr. Snelus' intermediate ladle of 20 to 30 tons, to hold an amount of metal equal to half a day's work of one of his three furnaces to the Cambria reservoir of 300 tons, holding three-fourths of a day's work of
570 one of their six furnaces, is a natural and inevitable result of our attempting to store our metal.

The blast-furnace metal storage reservoir at Cambria works is used in the same way as the cupola ladle, viz., it is filled with successive taps from the furnaces as the iron may be ready. Successive heats or parts of converter heats are drawn from it into the cupola ladle for conversion as required. In accordance with the natural way of using a reservoir, it is ordinarily kept well filled up. This reservoir incidentally equalizes to some extent the composition and temperature of the various taps put into it.

It is apparent to an engineer that with the growth of production of furnaces from 50 tons a day in 1875 to 400 to 600 tons a day in 1895, all apparatus is necessarily increased in size or capacity, which is adequately proportioned for the work today.

In reference to attempt to obtain uniform metal from *from* cupolas, the practice at Cambria works has for many years been to take all suitable metal to stock-house, in order as it is made to dump it into bins, and thence wheel it to the cupolas without attempting any selection of metal in making up a cupola charge, depending upon the blending of the various irons in transit through cupolas or cupola ladle to obtain a sufficiently good average for conversion. The only attempt to modify this average is by adding more or less scrap to cupola charge from time to time to give the necessary silicon, as determined by the blowing time of metal. The molten metal from the blast furnaces passes through the reservoir and to the converters necessarily in the same order, or as made by furnaces. There is thus no more care taken to obtain a mixture of various irons in one case than in the other.

Q. 10. Were you acquainted with the late A. L. Holley? What was his standing as an engineer and metallurgist in connection with Bessemer practice?

571 A. I was acquainted with Mr. Holley for a short time, being soon after my employment at the Cambria works in 1879 to 1882, when he died. He was regarded as the foremost authority of the world on metallurgy and apparatus of the Bessemer practice. He had been connected with the first installation of Bessemer plants in the United States, and was employed either as superintendent of same or in supplying the designs and drawings for the erection of nearly all the Bessemer works which were constructed in this country up to and including the Vulcan works in 1877. He was the superintending engineer of the construction of the Edgar Thomson works between the years 1873 and 1875, and prior to his em-

ployment as engineer of the Bessemer Steel Co., Ltd., in 1879, he was retained as an expert advisor of most Bessemer works, including Cambria, and I believe Edgar Thomson and others. In his regular employment as such he visited the various works frequently, and was in close and intimate communication with their engineers and managers. He visited Europe repeatedly, and from his acquaintance with engineers and managers abroad, was able to report upon the state of the art and the practice in various works to the American engineers.

Q. 10½. Have you read Holley's report of 1877, now in evidence, and what it discloses as to mixing and direct practice?

A. His report of 1877 is an epitome of the knowledge of the day and the practice of various European works on the direct use of blast-furnace metal in the Bessemer process. Almost all of his report bears upon the subject of storing metals. He says of direct practice:

"It has now been practiced long enough in Great Britain to test the commercial advantages of the system; to *to* show its incompleteness, and to suggest a remedy."

He says, after explaining the trouble from irregularity of silicon:

572 "The obvious remedy is to mix a number of blast-furnace charges, so as to reduce the irregularity to a minimum. Two systems of this are on the eve of trial; the one is simply mixing so few charges in a tank that the metal will be drawn out before it chills; the other is to store a large number of charges in a heated tank—that is to say, an immense open-hearth furnace."

This, to my mind, clearly discloses the method of mixing and of storage of metal of the patent in suit.

He then enters upon the history of the Bessemer process which has already been given in my testimony. He mentions Bessemer's suggestion of a large reservoir on wheels. He then discusses in details the practice at various works, viz: West Cumberland, in which he describes mixing in a charging ladle of portions of taps from two or three furnaces.

He says further:

"Mr. Snelus is about trying the experiment of placing a 20-ton ladle on a hydraulic lift at the 'A' pit, so arranged as to store, mix and pour, say three 6-ton to 7-ton blast-furnace taps, or to mix blast-furnace and cupola metal. No doubt this body of metal will live if the ladle is thickly lined and well covered."

Both of them I, as an engineer, consider embody the method of the Jones patent.

In mentioning the practice at Barrow, he says of the weights of heats:

"Their weights are very irregular; they sometimes run as low as four tons and are often eight tons."

This I may refer to as almost prohibitive of direct work.

He also mentions the practice at Dowlais and Ebbw Vale. He says further:

"The most unique works I have ever seen is nearly completed at

Moss Bay, a suburb of Workington," and describes in detail a proposed 60-ton or two 40-ton reverberatory coal-fired furnaces, into which it is proposed to put direct metal from the blast furnaces, to store it and keep it hot. The vessel charges are to be tapped out as required. He says: "Although this large furnace may be the best means of mixing metal so as to get a uniform result, the complex manipulations due to the arrangement described seem likely to take an unnecessary amount of time and labor."

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His criticism applies to the mechanical details of various lifts of the ladles. He suggests the difficulty of stopping the tap-hole of the furnace on account of the ferrostatic pressure, and suggests one way of avoiding the trouble. He states that Mr. Z S. Durfee has long advocated the use of a large Siemens furnace to melt and mix the metals for the converter. He alludes to mixing at Terre Noire and to direct metal at St. Chamond and Seraing. He sums up the paper by his conclusion, from which I quote:

"But if the storage of a large quantity of iron in a reverberatory furnace or other reservoir should prove successful, then a few blast furnaces making even an irregular product, and, if necessary, working in connection with cupolas, would largely economize the Bessemer manufacture.

"In fact, this mixing of irregular irons on a very large scale, thus avoiding the expensive niceties of ore selection and the necessity of many furnaces, is the theoretical key to the situation. When the way to its successful operation is demonstrated the direct process will undoubtedly have great advantages, even over the present practice on the continent, which employs manganiferous ores. But until this large scale mixing is developed, it should not appear that the use of our comparatively irregular blast-furnace metal, and more especially the use of part blast-furnace and part cupola metal, can result in any substantial saving."

"But the mixing problem is not such a difficult one. A small amount of flame, spread over a large surface of metal, should certainly keep it hot for a long time, seeing that the metal will keep hot in a ladle exposed to the air for an hour or more, and should there be any trouble about stopping the tap-hole in a large storing furnace, it could not be a very difficult or expensive matter (considering the Pernot revolving-hearth experience) to tip the whole hearth enough to pour a charge.

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"So that, while we congratulate ourselves that the direct-metal users have no large advantages over us in the present state of the art, we may look forward to the development of the metal-storing problem with good hope, not only of more economical manufacture, but of more uniform product."

In these conclusions are embodied such precise and definite suggestion as to mixing and the apparatus required therefore as to enable any engineer skilled in Bessemer work to construct an apparatus and work it successfully for carrying out the mixing operation, and I consider that it embodies all that is claimed in the method of the Jones patent.

My reasons for above conclusion are as follows: Take the first

system of mixing suggested as about to be tried, viz., mixing so few charges, etc. It is obvious that if a remainder is left in the tank at any time, as there assuredly often must be in drawing out measured charges, we have the usual method of using the reservoir ladle between cupolas and converters; and here evidently the intent is to use such an open ladle as is usual. This would seem to be the storage of a few charges and differs from the second method only in that it, the second, provides for "storing a large number of charges in a heated tank," or covered receptacle like an immense open-hearth furnace. Again, the obvious method of using the large reservoir is the one in which the reservoir or accumulating ladle is used in cupola work, viz., as fast as it is partially emptied into converters to fill it up by fresh charges, thus performing the precise operations which have been performed from the beginning of Bessemer work in America.

I have said that this method of using a reservoir is natural and inevitable, which I may also explain by saying that the word reservoir conveys to the mind of an engineer such a use as in water supply. A water reservoir is to be kept full by constant replenishing by pumping or by gravity additions, and being so kept as full as possible is thereby valuable as a reservoir of house or city supply; from which such quantities may be taken at any time as may be needed. If the reservoir is to be filled at one time on one side and drained empty at another time on the other side, it ceases to be such convenience, as we naturally expect to get in a reservoir, and an engineer who would use a reservoir in this fashion would be lacking in good judgment. To my mind the term reservoir in itself is sufficient to carry with it the idea of the method of the second claim of the Jones patent, and when the object of the reservoir is stated to be mixing on a large scale, I see nothing further to be conveyed to the experienced engineer to enable him to carry out the Jones method, when that claim is simply a detailed enumeration of the method of using a cupola ladle from the beginning of Bessemer work, and of the natural and usual method of using a reservoir anywhere.

I further consider that the suggestion of a tipping furnace reservoir embodies briefly all the valuable features of the Jones apparatus. Rotary furnaces of considerable size were well known in the arts prior to 1877. They were used in puddling and chemical operations by Danks, Sellers, Crampton, Bouvard, Russell and possibly others.

The best design of reservoir in use today for direct-metal storage may be described as a heated tank or immense open-hearth furnace, the hearth being tipping to pour the charges, so that clearly nothing but ordinary mechanical details were left to the skill of the engineer by Mr. Holley's suggestions.

Q. 11. Have you read the testimony of the various witnesses for the complainant as to the saving to be made by the use of a large reservoir or mixer? If so, state whether you, as an engineer, agree with them. If you differ, give your reasons in detail and give what you consider the saving to be.

A. I have read the testimony of Messrs. Gayley, Lauder,
576 Evans and Moreland. The saving made by applying the mixer is difficult to calculate, and data for it is not supplied by the testimony. In my opinion the saving is about equal to the increased expense. I have already shown the early direct practice at Edgar Thomson was very irregular as to weight of heats; and Mr. Lauder has so stated. It is deceptive to compare such inaccurate practice with an accurate practice, and attribute all the advantage to mixing, instead of to other reservoir advantages. Also in attempting to show the savings by mixing, Mr. Moreland, in A. Q. 2, compares cost by use of cupolas with direct practice, using a reservoir, and by implication attributes the saving of 65 cents to the use of the reservoir. The saving of 65 cents is due to saving of fuel, waste and labor at cupolos, and is obtained by any direct practice, whether with or without reservoir. Mr. Moreland had no knowledge of direct process without reservoir, as in answer to X Q. 38, he said:

"I know only of the mixer and cupola pra-tice particularly. Mr. Moreland showed that the direct metal gave a greater conversion loss than cupola metal. From the fact that it is generally higher in carbon and silicon content than cupola direct metal, it generally takes longer to blow than cupola metal. This difficulty a reservoir of the largest size does not overcome, as in Cambria practice our direct metal from a reservoir often takes 20 minutes to blow, or about double time of cupola metal, with additional cost for steam and wear and tear. Mr. Moreland produced no figures for this increased cost of direct metal, which is to be deducted from any saving."

As testified by Mr. Forsyth, the use of a reservoir *to* involves increased expense of interest, wages and repairs for maintenance of reservoir over and above the expenses of working direct without reservoir.

Mr. Lauder, in A. 2, says of direct work:

"We had a great deal of trouble on account of number of defective rails we made and the irregularity in the quality of the first quality of rails we sent out. The introduction of the mixer cured this matter completely."

577 This is the only benefit really belonging to mixer stated by the witnesses, and the only attempt to state this benefit specifically is in the testimony of Mr. Evans' A. Q. 16:

"We have reduced the defective or second-class rails fully one-half and also saved the remelting."

The saving of remelting, as before explained, belongs to any direct method, whether with or without reservoir. Lastly, from any saving of loss — defectives or improved quality due to use of reservoir must be deducted the labor and expense of providing, maintaining and operating the reservoir so that the net saving due to it is often nothing, and with the smaller works, operating part by cupolas and part by blast furnaces direct, it remains as stated by Holley in his 1877 report:

"Third. Unless a pair of vessels—a complete plant—can be

wholly supplied with direct metal, there will be little economy in using any, for it will take nearly as much labor, and more coal per ton of ingots, to remelt part of the iron as compared with remelting it all."

Q. 12. Have you examined the testimony of Mr. Thackray relating to the tests of the fixed mixer at the works of the Cambria Iron Company and the tabular and *and* graphic records showing the results of the same, and, if so, will you state the bearing of the same upon the patents or publications offered in evidence by defendants, and upon the question of anticipation of the Jones method covered by the patent in suit?

A. I have examined said testimony carefully. Its principal bearing is upon the Deighton English patent, and upon the second Witherow patent No. 377,425.

The fixed receiver at Cambria is somewhat smaller, but of the same general proportions as that shown on the Deighton patent, holding only about 75 tons. It differs from it in general construction only in the fact that it has a cover which would not affect its operation as a mixer of molten metals, and was a well-known Bessemer ladle constructed for years before the Jones patent, as
578 shown in several of the publications I have referred to, such as where Mr. Bessemer himself describes such a ladle for holding several converter charges and having "an almost closed top." The use of such a cover is the simple equivalent of the use of charcoal or coke dust on the top of the molten metal to retain the heat, a foundry and furnace practice for years. As described in the Deighton patent the molten blast-furnace metal was introduced into the fixed receiver, entering in a stream flowing over the edge, dropping into the receiver, and the metal entered this fixed receiver in the same way. The fact that it was carried thereto in ladles making no material difference. Metal from several furnaces was introduced in this way at intervals into the receiver and converter heats or charges withdrawn at intervals, this being the operation described in the Deighton patent. In so doing, in addition to the storing of the molten metal for use when needed, the different ununiform taps from the blast furnaces were mixed in the receiver, in the way described in the Deighton patent "to get a better average of metal which will be more suitable for making Bessemer steel or metal of uniform quality." In so doing, as above shown, the entire method of the Jones patent was also practiced.

The only essential point of the test of the fixed receiver (outside of the fact that it was used in accordance with the method described in the Deighton patent), was whether mixing and averaging of the quality of the molten metal actually took place in the metal so introduced. If it did it proves that the method described in the Deighton patent produces the results of the Jones method.

That such mixing and averaging of the quality of the molten metal does take place is demonstrated by the results of the tests at Cambria.

Taking those tables and diagrams the table of silicons of metal

put in shows considerable variation above and below the
579 silicon desired for working. The silicons of metal taken out show that the metals of various additions diffused and produced an average mixture better suited for working. The silicon determinations of metal going in and metal taken out shows an averaging the same as is shown by the tables in Mr. Gayley's testimony. Further, this is taken in connection with the time intervals so that the silicons may be plotted as has been done in the diagrams submitted, and the diagrams show very clearly how the high and low silicons of the additions make a much more irregular line and have more extreme variation than is shown by the silicons of the metals taken out which conform more nearly to a medium or average line. Thus the silicon and the time observations very clearly prove the averaging and the diffusion of the metals. To further show this the observation of weights of additions and withdrawals was recorded. Mr. Gayley's record also fails to show this at all and the weights are only material as they allow an approximate calculation of the silicon which should be obtained in the receiving vessel supposing diffusion was theoretically perfect. The weight of metal in the reservoir was determined by measuring, at the time of every withdrawal, and was approximately correct for each tap, error of observation not being accumulative. The calculated silicons show a remarkable coincidence with the actual observed silicons, proving that diffusion was prompt and as nearly perfect as could be expected. Taken altogether the test proves that it is not possible to pour fluid metals together into a reservoir without obtaining a tolerably thorough mixture, and that this mixture takes place without movement of the vessel or any stirring other than that obtained by pouring in additions and tapping reservoir.

The facts are briefly put in the following table of data and results of mixing molten metal with respect to % silicon·

580 *Range Shown by Figures Given in Testimony of George E. Thackray Relating to Fixed Receiver at Works of Cambria Iron Company.*

Date or period covered.	Sil. in metal put in per cent. Lowest.	Highest.	Dif.
Whole prd., 3¾ days	.59	3.15	2.56
1st day, July 28th	.66	1.56	.90
2nd day, July 29th	.59	2.79	2.20
3rd day, July 30th	.86	2.93	2.07
4th day, July 31st	.75	3.03	2.28
5th day, Aug. 1st	.92	3.15	2.23

Date or period covered.	Sil. in metal withdrawn. Lowest.	Highest.	Dif.
Whole prd., 3¾ days	.91	2.48	1.57
1st day, July 28th	.91	1.11	.20
2nd day, July 29th	.92	2.23	1.31
3rd day, July 30th	1.12	2.05	.93
4th day, July 31st	1.21	2.44	1.23
5th day, Aug. 1st	1.60	2.48	.88

As to the bearing of the test upon the Witherow patent No. 377,425, would state that the test receiver is similar to Witherow's in being a fixed covered vessel capable of being tapped at one or more places and holding a large bulk of metal, "receiving and storing the molten metal for the purpose of preventing the detention incident to the necessity of discharging the contents of the blast furnace when there is no converter ready to receive it," as stated by Mr. Bakewell in commenting on the Witherow patent when prosecuting the application for the Jones patent in suit. That mixing actually does take place in such a receiver as shown and described by Witherow is shown by the test of the fixed receiver, and considering the known fact that the metal differs in quality in different parts of the same blast tap as proven by Mr. Gayley, the method of the Jones patent is disclosed by Witherow and in
581 the inevitable tapping of one heat into metal remaining in the receiver the narrower method of the second claim will be necessarily practiced.

Q. 13. What connection, if any, have you with the erection and use of this fixed mixer in the Cambria works on which the test described in Mr. Thackray's testimony was made?

A. As chief engineer of the works I superintended the construction of the receiver and supplied the observers or workmen who observed the results of the test working under Mr. Thackray.

Q. 14. Can you state to what purpose this fixed receiver was built?

A. This fixed receiver was built to test the practicability of mixing in a fixed receiver, and the practicability of the use of such receivers as described in the Deighton and Witherow patents.

Q. 15. How practical did you find it to use such a fixed receiver for the mixing of the molten blast-furnace metal?

A. It was quite practicable to use such a fixed receiver as that of Deighton and Witherow and for the same purposes. We found that we were able to hold the metal in the molten state and to tap the metal from the receiver and to close or bott up the tap-hole when desired.

Q. 16. Mr. James Gayley, complainant's expert, in answer to Q. 6 states that: "It is essential to the proper manufacture of Bessemer steel that the metal should be uniform in the content of its impurities, particularly silicon, as this is the heat-producing element in Bessemer steel making." What is meant by such uniformity as referred to by Mr. Gayley, referring particularly to silicon content?

A. I would say that under average conditions silicon containing from one to two per cent. would give uniformity sufficient for good practical work.

Q. 17. Please state whether any of the patents or publica-
582 tions in evidence describe ways the same as the Jones method of mixing molten metals and which are calculated to produce such uniformity; and enumerate such patents or publications?

A. Should say that the Terre Noire method of '71, or earlier; the Durfee method; the method Mr. Snelus suggested in 1874, which was the intermediate method of American works used in 1865, as

described in the Iron and Steel Institute Journal for 1874; Mr. Snelus' West Cumberland method described in the Iron and Steel Institute Journal for 1876; Mr. Bessemer's method of reservoir on wheels described in the same journal, Mr. Holly's Vulcan Works method described in London Engineering in 1877; Mr. Fritz' method which is described in the Iron and Steel Institute Journal for 1878; which is also the large intermediate ladle 30 tons capacity; the Barrow method similar to Terre Noire method described in London Engineering 1880; the Rhymney method described in Jean's history 1880; the Whitney Foundry method dating back to 1853 described in article on Pennsylvania shops, London Engineering 1877, in which the Altoona wheel foundry is fully described; the wheel-foundry method described by Kirk in his "Founding of metals;" and the full description of the Holly report of 1877. As to patents, the Durfee and Abel Durfee patents; the Deighton patent of 1873; the Witherow patents of 1885; and the Bessemer patent showing the intermediate ladle. This is a brief summary of the most important at least.

Q. 18. Please answer the same question as to prior publication in this country?

A. The foundry practice of Wheeling, Whitney, Altoona, and Taylor Iron and Steel Company; the Bessemer reservoir ladle of all American steel works, dating back to 1866; the South Chicago mixing as testified to by Mr. Forsyth; the Vulcan practice described by Mr. Holley in 1877. The other foundry uses referred to in my answer No. 5 are the same in principle.

583 Q. 19. Mr. Gal-ey also says in his answer No. 6, referring to the use of the Jones mixer, that the metal in the mixer remaining for a long time in a hot state renders this (the obtaining of a uniform charge of blast-furnace metal) feasible. Is any considerable time necessary for the mingling of molten metals when introduced into a vessel, where the metal is taken from more than one source?

A. No considerable time is necessary for diffusion or mixture to take place; in all probability it is principally effected by the act of pouring, or takes place a few minutes afterwards. That this is recognized is shown in the Altoona Foundry practice, where they took tests immediately after the metal was tapped from the cupolas into the reservoir. The fact is well recognized that ferro-manganese added to a ladle of molten steel promptly melts and diffuses, and the steel is poured into the ingot moulds as soon as the ladle can be brought into position over the moulds.

Q. 20. In this same answer No. 6 Mr. Gayley says:

"In the operations of the metal mixer the object is to keep together a large amount of metal in order to secure a thorough admixture, and also to keep the mixers constantly full."

Is there anything in the Jones method (patent) limiting it to keeping together a large amount of metal or to keeping the mixers constantly full?

A. Certainly not, as the specification described that the operation may be performed in an ordinary charging ladle, which at that day

contained about two heats, and the only requirement of the patent (and this only as to the second claim) is that the ladle or receptacle shall not be entirely drained in taking the charge from it.

Q. 21. Does the prior art disclose the keeping of large bodies of molten metal in a liquid condition, and, if so, please refer to a few examples?

A. Practically all the patents and publications referred to in my answers 17 and 18 would show this, in view of the uses de-
584 scribed which would require it. Mr. Durfee says in his letter to the London Engineering that he has known iron to be kept in a hot and fluid state for several hours. In the Journal of the Iron and Steel Institute of 1876 Mr. Smith, of Barrow, stated that they carried ladles full a mile and a half to two miles, which took half an hour, but that on account of difficulties on the railroad the trains were arranged to run once an hour. Mr. Holley, in his article on the Vulcan works, says:

"Cast iron will live in thickly lined ladles when covered with charcoal for several hours."

In the 1877 Holley report this storing of metal for a considerable time is fully commented upon, showing it to be recognized as thoroughly feasible. The increased size and capacity of ladles diminishes the loss of heat by radiation, and decreases the difficulty of storage on this account. The capacity of the Jones storage reservoir may be estimated at say one tenth of a day's work, or about two and two-thirds hours' storage. This is less time than Messrs. Durfee, Holley and others state is entirely feasible to retain iron fluid.

Q. 22. Is there anything in the Jones method (patent) in suit which limits it to the practicing of the methods described therein in a covered ladle or receptacle, so far as you have examined it as an engineer?

A. There is nothing which limits it to a covered ladle, as the specification distinctly says it may be practiced in an ordinary charging ladle, which has no cover.

Q. 23. Please compare the size of the Cambria reservoir, the use of which is complained of in this case, with the large ladle of the Jones patent, and the ladles of the prior art?

A. We will take the Edgar Thomson capacity as shown by the statement by Mr. Lauder in answer 12, year 1895, at about 1,500 tons *per diem* ingot capacity. This is about ten times the
585 weight of the metal storage of the two receivers as shown by Mr. Gayley's testimony, for, as I before said, they have about two and two-thirds hours' storage capacity of metal. In 1887, according to Mr. Lauder's testimony, the ingot tonnage was about one-half this amount of 1895 and the patent describes one mixer so that the relation of ingot and storage tonnage was about the same, about ten to one. Taking Mr. Snelus' discussion in 1878 of Mr. Fritz's proposed apparatus of the 30-ton ladle at Bethlehem, those works at that time were making probably about 300 tons per day, so that the ratio of this ingot tonnage to the proposed storage was the same as the present Edgar Thompson apparatus and ingot ton-

nage. The Deighton apparatus may be considered to have shown apparatus for storing metal from four blast furnaces which at that time and place and country would produce about 200 tons per day, while the reservoir had a capacity of about 100 tons, which would be one half day's supply. Another example of large relative storage capacity is in the Holly report of 1877, where he mentions a 60-ton storage furnace and two 40-ton storage furnaces as being projected at Moss Bay. These works had four blast furnaces when I visited there in 1884, and the tonnage of the furnaces was probably 50 tons per day (at the time of Holley's report) for each furnace, or 200 tons in all. Here again we have example of a large reservoir capacity as compared with the metals to be stored. The Cambria reservoir was designed for an ingot capacity of 1,600 tons per day and the reservoir is 300 tons, or about one-fifth of a day's supply, so it will be seen the Cambria storage capacity is relatively smaller than the prior art as shown by Mr. Holley, while the Edgar Thomson storage capacity is much below that provided either by the Deighton patent or the Holley report of 1876.

Q. 24. I call your attention to Exhibit Blue Print No. 2, defendant's mixer, and to Exhibit Rejected Half Blue Print No. 2,
586 and especially to the arrangement of the cupolas in said rejected half. Please state how correctly said drawing shows the arrangement of the cupolas at the defendant's works?

A. The drawing is a correct representation of the present Cambria plant.

Q. 25. I call your attention to the arrangement of the cupolas and runners therefrom to feed the metal from the cupolas into the charging ladle as shown in Exhibit Rejected Half Blue Print No. 2. Please state how long the Cambria Company have employed that arrangement of a number of cupolas with runners therefrom leading to a common point to feed the metal into a charging ladle?

A. The drawing in question shows the new plants of the Cambria Company. Five cupolas on the right-hand side of the drawing have been in use since 1889 substantially as shown. Two additional cupolas to the left of the group of five were added a year or two later. The old plants of the Cambria Company are not shown in the exhibit, having been demolished. In the old plant we used a group of six cupolas leading by branching runners into the charging ladle. That plant was in use since the beginning of the Bessemer practice at Cambria, since 1870, I think, the date of the starting of the old plant. It may be further explained that the works were originally started with three cupolas, others being added from time to time. In the early plant, as well as the later, there was a common receiving ladle, or rather I should have said two receiving ladles, the arrangement being changed slightly in detail from time to time.

Q. 26. To make it clear, please state whether in the old plant, where you had a series of cupolas which you say commenced with three and ended with six, there were runners extending from these cupolas to a common point at which the metal was fed from the several cupolas into the single discharging ladle.

A. There were runners extending from the cupolas to a
587 common point at which the metal was fed from several cupolas into the charging ladle. In the earlier plant there were two charging ladles, and a trough could be swung from one to the other to feed either ladle, as desired. About 1880 the two ladles were taken out and a larger ladle on a lift substituted therefor, but from the beginning we had a ladle or ladles fed at a common point from the number of cupolas which were at work.

Adjourned to meet again January 22d, at 10.30 a. m.

JANUARY 22, 1897—10.30 a. m.

Met pursuant to adjournment.
Present: Counsel as before.

JOSEPH MORGAN, JR.—Examination continued.

Cross-examined by counsel for complainant:

Reserving any exceptions which may be taken to the examination-in-chief during the cross-examination.

X Q. 27. In your testimony you very frequently in expressing your opinion say that you do so as an "engineer." What limitation do you understand that the use of this expression puts upon statements which you make, and what is there in the state of the art to which you have referred, or to the nature of the issues in this case as you understand them which suggested to you so carefully to make that limitation?

A. In stating that I am an engineer I simply state my profession as a matter of fact and that my opinions are those of an engineer. I am not aware that there is any particular care exercised, but in my judgment and opinion an engineer is best qualified to pass upon the state of the art. I think I have answered the question fully.

— Q. 28. Do you understand the question that I put you?

A. I have already answered the question as I understand it.

X Q. 29. I now ask you what there is in the state of the
588 art to which you have referred in your testimony-in-chief, or to the issues involved in this suit, as you understand them, which caused you so carefully to state that you expressed your opinions as an engineer?

A. In my opinion the whole state of the art as given in my direct testimony from the inception of the Bessemer invention to the date of the Jones invention can best be understood and passed upon by an engineer, and it is for that reason that I emphasized the fact that I was such a person.

X Q. 31. How does your understanding of the functions of an engineer differ from your understanding of the functions of an expert in giving testimony in a suit such as this?

A. In my understanding an engineer is an expert, or should be, in the line of engineering by which he makes his livelihood.

X Q. 32. I understand the term engineer refers to the construc-

tion, mechanical operation and designing of engines, structures or devices, for the performance of certain physical functions. Is this your understanding?

A. It is not.

X Q. 33. Please state what your understanding is.

A. An engineer familiar with metallurgical operations and designing all the apparatus used in a large works has necessarily a much broader knowledge than of merely mechanics.

X Q. 34. In what capacity do you undertake to interpret the meaning and scope of the patent in suit?

A. As an engineer with considerable familiarity with the metallurgical operations and the state of the art in question.

X Q. 35. When did you first become practically acquainted with what is known as the Jones mixer?

589 A. I cannot give any exact date at which I first saw the Jones mixer. I saw it several times at the works of the complainant, from the beginning of its operation to the present time.

X Q. 36. When you first saw the Jones mixer was it before or after you introduced it into the Cambria iron works, of which you are engineer?

Objected to as based on the unwarranted assumption that defendant introduced the Jones mixer, which is, in fact, the subject of a separate patent not here in suit.

Complainant's counsel protests against the making of instructing objections in the presence of witness.

A. I saw the Jones apparatus before the installation of the reservoir at the Cambria works.

X Q. 37. Did you not, while Mr. James Gayley was superintendent of the Edgar Thomson steel works, visit him at the complainant's works at Braddock, Pa., and consult him as to the best mode of constructing and installing the Jones mixer in the Cambria iron works?

A. I recollect visiting Mr. Gayley and talking over storage of metal, but as we never intended to install a Jones apparatus, have no recollection of consulting him about such installation at Cambria works.

X Q. 38. Mr. James Gayley is here present in this room and now tells me that the conversation which you had with him at the time referred to was substantially as follows:

You asked Mr. Gayley his opinion as to the best capacity and location of a metal mixer to get the best results, and he showed you a sketch of a new mixer of large capacity which complainant then contemplated building; you stated that the defendant intended to install a metal mixer at defendant's works and in talking of it the term you used to designate it was metal mixer; that in your conversation you showed yourself familiar with the construction and operation of the complainant's mixer. Further, that Mr. Gayley

590 gave you freely his opinion based upon his experience with complainant's Jones mixer and stated that he would prefer a mixer of 300 tons capacity and would prefer to locate the

same at the Bessemer department of the works, it being understood that the metal should be carried from the mixer in ladles and taken from the mixer in ladles; that you explained that you intended to put your mixer at the Bessemer department. Further, that all this was prior to the building of the defendant's mixer and was when complainant'a Jones mixer had been in constant operation for a number of years. Has Mr. Gayley informed me truly on this point?

The question is objected to, first, as irrelevant and immaterial; second, as matter which if having any relevancy at all to the issue in this case, should have been developed as part of the complainant's opening case, especially as the witness, James Gayley, was examined at length as one of the complainant's witness-. Third, that it is not proper cross-examination, there being nothing whatever in the direct examination of the witness bearing on the subject, and, fourth, that if the question is asked for the purpose of laying grounds for rebuttal, it does not include that which is a necessary part of it, namely, the time of the alleged conver-ation. And it is requested that before the question be put to the witness, especially in view of the presence of Mr. Gayley, which is stated in the question, the time of the alleged conversation be added to the question.

By COMPLAINANT'S COUNSEL: If there were several such conversations in which the witness made these statements before installing his mixer, and he wishes to know which one I mean, he may so state and ask me.

Defendant's counsel insists upon what he believes to be the general rule in laying grounds for rebuttal, namely, that the time of the supposed conversation shall be fixed, and this especially in view of the presence of Mr. Gayley at this examination, and the intimation of counsel that he is able to fix the time.

591 A. I cannot undertake to answer as to details of the conversation so long ago. My clear recollection, however, is that Mr. Gayley is mistaken in saying that he showed me a sketch of a large mixer, as he spoke of such a mixer, but did not show the sketch. My further recollection is that I came away convinced that the Jones apparatus had very grave defects.

X Q. 39. You will notice that I did not ask you for your opinion, and I will thank you to confine yourself to answering the question as put. Will you now please state to me any other particular except in the matter of the sketch in which Mr. Gayley has incorrectly reported to me the substance of his conversation with you at that time.

Objection continued.

A. I believe I had a conversation with Mr. Gayley, but do not undertake to say that this is all or correct as to terms. In a general way, we had such a conversation.

X Q. 40. I now ask you whether the conversation which Mr. Gayley has told me of, and to which you refer, did not take place in the latter part of the year 1894, or early in the year 1895?

Objections continued, except the fourth objection as to question 38, and the question is further objected to now that the time has been fixed as indicating a time long after the installation of the metal reservoir used by the Maryland Steel Company, and therefore shown to be entirely immaterial to an issue in this case. Said Maryland Steel Company mixer being substantially the same construction and substantially the same location as referred to in question 38.

Complainant's counsel remarks in reply that we are now taking testimony in suit against the Cambria Iron Company.

A. My recollection is that it was probably about the time named, as about that time we were completing plans for installing an Aiken reservoir.

X Q. 41. How long after this conversation was it that you built the mixer at the Cambria works at Johnstown, the use of which is the subject of this suit?

592 Objections continued to this entire line of examination.

A. Mixer was built (the witness requests the word "mixer" to be stricken out and the word "reservoir" substituted) during the year 1895, and put in operation in November the same year.

X Q. 42. Was it in consequence of your coming away from this conference with Mr. Gayley that "convinced you that the Jones apparatus had very grave defects," as you have said in your answer to cross-Q. 38, that you made the changes in the construction of the mixer in those respects in which defendant's mixer differs from the Jones mixer as shown in the patent in suit?

A. I have already stated we never intended to install a Jones apparatus, and at the time of my visit to Mr. Gayley we had plans of the Maryland and South Chicago apparatus which in our judgment were much better, so that the conversation with Mr. Gayley did not change my judgment.

X Q. 43. What changes from the construction referred to or explained to you by Mr. Gayley did you make in the mixer which you installed at the Cambria iron works? Please to state all the particulars in which the mixer installed by you in the Cambria works differs in construction from that shown in the patent in suit and the purposes of such differences.

A. Mr. Gayley did not explain to me the details of his apparatus proposed and I cannot therefore explain the differences between that and the Aiken mixer or reservoir which we adopted and introduced. The Jones apparatus shown in the patent is a rectangular-roofed reservoir holding a mass of metal approximately wedge shaped the reservoir rocking upon a bottom pivot so that in the act of pouring the centre of gravity of the mass of metal is moved forward. In the Aiken apparatus which we have installed the reservoir is cylindrical in shape with slightly convex ends and the reservoir in turning revolves upon the centre of the cylinder, so that there is no material movement or change
593 of centre gravity of metal. The mechanical details of the Aiken reservoir are entirely different to that shown in the

Jones apparatus. It is supported upon cradles of rollers and the motion is imparted to the reservoir by hydraulic cylinders. The drawing of this reservoir is in evidence showing complete details thereof.

X Q. 44. Please to state all the purposes of the various differences which you made in the mixer apparatus which you constructed and installed at the Cambria works and those shown in the Jones mixer as shown and described in the patent in suit.

A. The hypothesis that the Jones apparatus was the basis on which our design proceeded is not correct. The type of apparatus upon which our apparatus is based and founded goes back to the rotary furnace the nearest type of which is the open-hearth tipping furnace of the Pennsylvania Steel Company.

X Q. 45. Having now made the statement contained in your last answer, will you please proceed to answer the last question (my last question)?

A. I do not think I shall give reasons for differences in design when such reasons were not part of our consideration in making the design or adopting the same.

X Q. 46. Please now to answer cross-question 44 as put to you.

A. I will endeavor to state points of superiority of the Aiken apparatus over the Jones apparatus as they occur to me. The Aiken apparatus is semicylindrical and has the advantage of exposing less surface for a given quantity of metal contained than the rectangular shape. The ideal shape would be that of the Bessemer construction a spherical ladle suggested in publications in evidence. The cylindrical shape is approximately next best. The rotation about the center of gravity of a vessel firmly supported on roller beds is safest and requires least power. In a general way
594 these points embrace the ruling reasons which would induce an engineer to select either design.

X Q. 47. Are these all the points of difference which now occur to you, and, if not, state any others which do occur.

A. Well, it may be further said that cylindrical shapes such as ladles and vessels of that character require less external support and are more easily cleaned than a shape having flat surface and internal angles.

Adjourned here until 2.30 p. m.

X Q. 48. Counsel for the complainant requests the witness if by what he calls the Aiken apparatus in the answer to 46 cross-question he means the defendant's apparatus at Cambria to so designate it in his answers in order to avoid confusion and not to call it the Aiken apparatus. Are you not mistaken in your answer to 46 cross in stating that a semicylindrical apparatus exposes less surface for a given quantity of metal contained than does the rectangular shape?

A. The apparatus at the Cambria works is similar to that at Sparrow Point, both of which are designed by Mr. Aiken and the apparatus at the Cambria works was also constructed by Mr. Aiken as contractor. I therefore properly designate it as the Aiken type

of apparatus in distinction to *to* the Jones type. If Mr. Bakewell will state proportions and dimensions of apparatus of semicylindrical and rectangular shape I will endeavor to calculate and test the correctness of my answer. As to the spherical shape I am quite sure that my answer is correct. The nearer a vessel approaches to a sphere in shape the more nearly it will reach the desideratum of minimum external surface for a given internal content.

X Q. 49. Take the circumference of a semicircle of 20 feet diameter, how much is it?

A. 31 and four-tenths feet.

595 X Q. 50. Now what is the circumference of a square rectangular figure around that semicircle. Is it not 40 feet?

A. Quite correct.

X Q. 51. What would be the sectional area of a semi-cylindrical vessel 20 feet in diameter?

A. About 157 square feet.

X Q. 52. What if the area of a rectangular vessel 20 feet diameter subtending the semicircle of 20 feet diameter?

A. 200 square feet.

X Q. 53. Exposed surface of the metal in both vessels would be 20 feet across, would it not?

A. It would be 20 feet across and also the surface of the vessel containing the metal. The 20 feet being only the top surface.

X Q. 54. And the cubical contents of both vessels would be the cross-sectional area multiplied by the length, would it not? In other words, the cubical contents would be in proportion to the cross-sectional area. Am I not right?

A. With the necessary correction for end surface of vessels, which is also exposed surface, the relation between the capacity and surface depends upon the entire surface, both of sides, ends and tops of the vessel. Also making necessary correction in the Aiken vessel for the approximately spherical ends.

X Q. 55. Please to answer the last question as put to you.

This line of examination is objected to as incompetent and improper, being based on assumed forms and proportions of vessels which do not appear from evidence in this cause.

A. That is correct.

X Q. 56. Take two vessels, one cylindrical and the other
596 rectangular, each 10 feet deep and of equal width and length and both half full of metal or other contents, which has the greater content?

A. One is a ten-foot cube and the other is ten-foot diameter, ten-foot-long cylinder. The cubical content of the cube is 1,000 feet cubic, or 500 when half full. The cubical content of the cylinder is 785 cubic feet or 392 cubic feet when approximately half full.

X Q. 57. You have stated all the material differences of construction between the mixer shown in the patent in suit which we have called the Jones mixer and the defendant's mixer at Johnstown. Now please state all the material differences between the mode of handling the metal in the use of the defendant's mixer at Johnstown

and the mode of handling the metal in connection with the Jones mixer as *of* shown in the patent in suit?

A. Before answering the question I would like to inquire what is the method of handling in the mode of mixing of the patent in suit referred to.

X Q. 58. If I am not mistaken you have in your testimony-in-chief spoken of the method of the Jones patent, not once but repeatedly, and your testimony-in chief assumes if it does not positively state your acquaintance with the patent in suit and the method of treating pig metal in the mixer therein described. I have therefore a right to suppose that you must understand the question which I have put to you. By the method in the use of handling the metal in connection with the Jones mixer shown in the patent in suit I mean what you have called in your testimony the method of the Jones patent?

A. At the Cambria works we bring ladles from the blast furnace and pour it into the reservoir for blast-furnace metal. This metal is brought at times convenient for tapping the furnaces and with view of keeping up the supply sufficient for the converting works, the vessel being filled with a sufficient supply. It was drawn from time to time from the reservoir into the iron ladles and very
597 often receives additional supply of metal from the cupolas. In the language of Mr. Holley our practice may be described as that of storing, mixing and pouring from the reservoir, the mixing being incidental to the use of the reservoir. The method of the Jones patent as shown is of two kinds. That of the first claim, which includes pouring metal from different sources into the common reservoir and this method is necessarily practiced at Cambria works and other places where metal from different sources is poured together into a common vessel. With the exception of additions of cupola metal, I do not know that there is any material differences between our practice and that described in the second claim.

X Q. 59. In your direct examination you have said:

"Again the obvious method of using the large reservoir is the one in which the reservoir or accumulating ladle is used in cupola work, viz., as fast as it is partially emptied into converters, to fill it up by fresh charges, thus performing the precise operations which have been performed from the beginning of Bessemer work in America. I have said that this method of using a reser*y*oir is natural and inevitable, which I may also explain by saying that the word reservoir conveys to the mind of an engineer such a use as in water supply. *Water reservoir is to be kept full by constant replenishing by pumping or gravity additions, and being so kept full if possible is thereby valuable as a reservoir of house or city supply, from which such quantities may be taken at any time as may be needed.*"

Do you wish by this statement or by the context to be understood as meaning that the part of the above quotation which I have italicized correctly represents by accurate analogy the mode in which the defendant uses its mixer at the Cambria works?

A. I do believe the analogy is close. The term reservoir is one given to the apparatus by Mr. Holley both in the London engineer-

ing article upon the Vulcan works, and also in his '77 pamphlet upon direct metal. These articles I have quoted in my testi-
598 mony. I consider that today with the large productions of modern furnaces the reservoir function is the predominent one which would lead to the installation of such apparatus in working metal direct from the blast furnace.

X Q. 61. One of the witnesses in this case has testified as to the presence of a chalk mark placed on the outside of the mixer vessel at the defendant's works to indicate when the vessel was tipped so far as to leave in it only 175 tons. Who put or directed the putting of that chalk mark on the mixer?

A. I do not know.

X Q. 62. Have you seen the chalk mark there?

A. I have some recollection of the chalk mark on the end of the reservoir in the early days, but my impression is that the necessities of the converting works predominate and the height of metal fluctuates to a considerable extent. I do not know of any regulation on the subject. Say for practical reasons which apply to all storage vessels including the long-used cupola ladle the best practice is to keep them well filled up.

X Q. 63. Will you please state the dimensions of the mixer of the defendant and its distance from the blast furnace and converters respectively?

A. The converters are distant from the reservoir approximately from 20 to the nearest converter to say about 100 to the most distant. This is shown on the drawing submitted. I do not recall exact dimensions. The distance to furnaces I also do not recall, and it probably varies from 600 to 2,000 feet.

X Q. 64. Prior to the time of your conversation with Mr. Gayley, about which you have been questioned, had you seen and examined the Jones patent in suit?

A. I believe I had.

X Q. 65. As I understand the operation of the defendant's mixer at Johnstown, the metal from the blast furnace is not run
599 into the mixer through a trough or runner from several furnaces at once, but is carried thereto on ladles mounted on wheels, and the contents of these ladles are poured successively into the mixer. Is this correct?

A. That is correct.

X Q. 66. What is the weight of the ordinary tapping from one of the defendant's blast furnaces?

A. That is changing from time to time. Of furnaces now producing about 400 tons per day maximum, the tap is three or more ladles from each furnace.

X Q. 67. As I understand you then, each tapping of the blast furnace is run into three or more ladles, and is therefore not poured all at one pouring into the mixer, but the contents of the several ladles are poured thereinto successively?

A. Necessarily so.

Adjourned until 10.30 January 23rd, 1897.

Met, pursuant to adjournment, January 23rd, 1897, at 10.30 a. m. Present: Counsel as before.

X Q. 68. The patent in suit refers, does it not, to the treatment of the crude product from a number of blast furnaces?

A. It does, and also to molten metal.

X Q. 69. What molten metal?

A. Any molten metal whether from blast furnaces or other means of melting metal.

X Q. 70. Is there any other metal referred to in your last answer than is referred to in the specification in patent?

A. I understand the term molten metal to include any molten metal and so interpret the specification.

X Q. 71. Please to quote without comment any portion of specification of patent in suit which refers to any other molten metal than melted pig-iron product of a blast furnace.

600 A. I so interpret "my invention is not limited to its use in connection with converters since similar advantages may be obtained by casting the metal from the mixing vessel into pigs for use in the converters, puddling furnaces, and for any other uses to which pig-iron metal — put in the art;" and I so interpret the words of the second claim, "in the art of mixing molten metal," in view of the fact that the first claim is limited to refining iron directly from the smelting furnace, and my further reason- for so interpreting these words are the facts that the application was twice rejected on a reference to a foundry practice which application to foundry practice is not disclaimed in a letter of Mr. Bakewell on this rejection.

X Q. 72. What is the reason for your deliberately disregarding the instructions which I gave you in my last question as to answering it by quotations from the specifications without comment?

A. My reason is that in matters of opinion I believe I have a right to give my reasons.

Counsel states to the witness that it is his duty to regard instructions given to him in the question and to answer them as put, and that we shall expect him to regard this instruction in the future in answering questions put to him.

X Q. 73. Do you not consider that the meaning of terms used in the specification such as metal and molten metal is to be governed by the nature and object of invention as stated therein?

A. Yes, including the title of specifications and the accepted meaning of the words in the claim as well as specification.

X Q. 74. The title of the patent specification is the "Method of mixing molten pig metal," is it not?

A. Yes.

X Q. 75. Then in view of what you have stated would it
601 be correct to say that the patent in suit referred to any other metal than the crude metal obtained from blast furnaces ordinarily called molten pig metal?

A. I think it would not be correct, as molten pig metal is not necessarily obtained directly from a blast furnace.

X Q. 76. Could you take the metal from your mixer at Johnstown and use it successfully for making castings? Would it not be too cool for such purposes?

A. Given proper iron and other proper conditions such use could be made of a reservoir as is shown by the car-wheel-foundry practice. I cannot answer definitely a question so vague in its conditions.

X Q. 77. I beg to remind you that you have again disregarded my instructions, and I think are going beyond your duty as a witness. Will you please answer this question directly?

The counsel for defendant instructs the witness that he is to answer the questions as directly and fairly as possible, but that he is at liberty to couch his answers in his own language and in such manner as to prevent his meaning from being misunderstood or misconstrued.

By Mr. BAKEWELL: I join in the instructions, Mr. Dodge, and trust that the witness will in future fairly observe the caution that his counsel has given him. Mr. Dodge has said just what I meant, and we shall have no trouble if you will obey his instructions.

X Q. 78. Will you now state whether using your mixer as you use it at Johnstown for the purpose of furnishing iron for the purpose of making Bessemer steel, could you draw off the iron from the mixer during its ordinary working, and use the same successfully in making general castings?

DEFENDANT'S COUNSEL: Objected to as immaterial. The patent in suit extending to the manufacture of iron also for "puddling furnaces or for any other uses to which pig iron may be put
602 in the art." While the special use in question is under conditions incident to one only of the uses named in the patent. Complainant's counsel replies that the objection is misleading, in that it is an incomplete quotation in the patent, and does not give the full sense of the paragraph stated.

A. Not being a foundryman, I do not think I can answer your question more definitely than in answer to question 76. Given proper iron and proper temperature, castings could no doubt be so made.

X Q. 79. You notice that the question is whether the iron in the mixer is proper iron and is at proper temperature. Can you, and if so, will you answer this question, I mean proper for making general castings?

A. I have endeavored to answer the question, and will add that Bessemer iron is not ordinarily used in foundry practice except with admixtures. I may further say that I am not an expert foundryman.

X Q. 80. Do you not at Cambria make your ingot molds from Bessemer iron?

A. Our ingot molds are made from Bessemer iron specially selected for the use. I do not know whether the iron in the reservoir

would correspond to our selection of mold iron. In your previous question you used the words "general castings."

X Q. 81. Do you wish us to understand that the conditions of the molten blast-furnace metal in your mixing reservoir at Cambria and the conditions of the melted metal in the ladle from cupolas are identical?

A. They may be and doubtless often are.

X Q. 82. In your answer to the fourth direct interrogatory, you have stated that the method of mixing molten pig metal is for the purpose of obtaining so good an average of molten pig metal as is necessary preliminary to a refining process, or for other uses in the art. State for how long a time at the Cambria works the blast-furnace process has been in operation, and whether by the term re-
603 fining process in the passage I have quoted refers to the Bessemer converter process, and what means you used prior to the introduction of your mixing reservoir for securing the necessary preliminary mixing?

A. Since November, 1895, we have used the reservoir, as I have previously stated. The term "refining process" includes use in converters, puddling furnaces and open-hearth furnaces, or any other refining process known in the art. Prior to the introduction of the reservoir for blast-furnace metal, we procured our molten iron from cupolas which were charged with solid pig iron taken promiscuously as it came from the blast furnaces and with suitable proportion of scrap. The metal from the various cupolas was tapped into the cupola ladle and there mingled. From time to time heats were drawn from this ladle, which was refilled by additions from the various cupolas. The number of cupolas and the use of the ladle in front of them secured the necessary preliminary mixing. The method of charging the cupolas is described in detail in the previous testimony of Mr. Price.

X Q. 83. In your examination-in-chief, you have referred to several methods or practices as described in various patents and publications which are the practice at Terre Noire in 1867 as described in the French patent. In the English patent Bessemer 1869, in the Abel-Durfee English patent of 1872, in the Deighton English patent of 1873, in the remarks of Mr. Snelus in regard to the necessity of use of an intermediate vessel as recorded in the Iron and Steel Institute proceedings of 1874, in the Durfee letter in London Engineering in 1874, in the remarks of Mr. Snelus, in the report of the proceedings of the Iron and Steel Institute in 1876 and the remarks of Mr. Bessemer at the same time, in the Holly report of 1877, in which he speaks of a 20-ton ladle of Mr. Snelus', in the remarks of Mr. Snelus on Mr. Holland's paper in reference to the Moss Bay works, in the proceedings of the Iron and Steel
604 Institute of 1878 and the reference in the same report to Mr. Fritz' 30-ton ladle in Jeans' History of Steel, in the reference to the Rhymney works, a quotation of Layborne's paper read in 1877 and '78 for the South Wales Institute of Mining Engineers and in an article in London Engineering of 1880, being a description of the Barrow works. Please to state which if any of the several processes

or methods described or specially referred to in the foregoing patents and publications were practiced at the Cambria works during the time that you were there and prior to the introduction of the mixing reservoir, installed in 1895, and by practice at the Cambria works I mean practice in the specific manner described in any of said patents or publications which you may say you have used.

DEFENDANT'S COUNSEL: Objected to as immaterial and foreign to the issue of this cause.

A. The Snelus suggestion of '76 of an intermediate reservoir, the same as used in America, and the Fritz suggestion of a 30-ton ladle, undoubtedly convey the idea of the use similar to the American reservoir ladle which has been in use at Cambria works from the beginning of the Bessemer process.

X Q. 84. And were these all?

A. The English Bessemer patent of '69 including the use of intermediate vessel between cupolas and converters is the same type as the American cupola ladle, with exception of being fixed and tapping instead of turning.

X Q. 85. You mean to be understood as saying or implying that at the Cambria works prior to 1895, you used such intermediate ladles or vessels for taking metal directly from the blast furnaces to the converters, or for supplying the converters with metal that had not been remelted in cupolas?

A. The intermediate vessel at Cambria works was used with cupola melted metal only.

605 X Q. 86. How long has the Cambria Iron Company been using pig metal from its own blast furnaces for making Bessemer steel?

A. The Cambria works have used as some of their pig metal necessary to supply their converting works, the product of their own furnaces at Johnstown, Conemaugh, Bennington and Hollidaysburg, since my knowledge of the works in '79, and possibly before. This was supplemented by purchased additions up to a recent date. All of this was used by remelting up to November, '95.

X Q. 87. How long has the defendant been using in this way the product of its furnaces at Johnstown?

A. I think, as I have stated before, from the beginning of Bessemer work there, but some of the Johnstown furnaces up to about 1880 made mill iron, so that there was but a partial supply at Johnstown.

Adjourned here to 2.30 p. m.

X Q. 88. How many blast furnaces were there at the defendant's Cambria works at Johnstown prior to 1880?

A. My recollection is that we had two 20-foot furnaces and four old furnaces of small size.

X Q. 89. Were these blast furnaces at the same distance from the converters?

A. Blast furnaces are in approximately the same position as in 1880.

X Q. 90. Were you not present about December, 1885, at the defendant's works at a meeting of Captain W. R. Jones, the patentee of the patent in suit, and Mr. James Gayley with Mr. Fronheiser (then the superintendent of the defendant's blast furnaces) who showed to Captain Jones and Mr. Ga-ley the following apparatus which the defendant had installed preparatory to using in the converters metal taken directly from the blast furnace, viz: gas hoods for drying the ladles to be used for taking the metal to the converters, arranged to be heated by furnace gas, and tracks
606 leading to the furnace cast-house put in especially to receive the molten metal in ladles and transport it to the converters; and in answer to a question by Mr. Gayley or Captain Jones asking when you intended to begin using the direct process, did not you or Mr. Fronheimer reply that you were waiting to see what success would be made of the direct process at the Edgar Thomson steel works?

DEFENDANT'S COUNSEL: Objected to as not proper cross examination and also as irrelevant and immaterial, relating to a matter long prior to the making of the invention covered by the patent in suit.

A. My memory entirely fails to recall any such interview.

X Q. 91. Was it not the fact that such preparation for the use of direct metal for the converters was made about that time?

A. I do not recall exact date, but we did install some apparatus looking towards the direct process, completion of which was deferred pending reconstruction of the Bessemer works.

X Q. 92. And was this apparatus ever used for any other purpose prior to 1895?

DEFENDANT'S COUNSEL: Objection continued to this question, to the previous one and to this entire line of examination.

A. Yes, part of it was put to a temporary use in the old works.

X Q. 93. How much of it, when, for how long, and for what purpose?

A. Hydraulic ladle hoist was put in temporary location in front of old cupolas and some of the ladles were there used as cupola ladles. The instal-ation of this lift and ladles I cannot now give exactly, but it was in use several years prior to the operation of the new works in 1889.

607 X Q. 94. But as I understand you this apparatus was not used for the transportation of molten metal direct from the blast furnaces prior to 1895?

A. You are correct.

X Q. 95. Will you please state with reference to the operations at Terre Noire as described in the publications to which you have referred the points of difference between those operations and the operations involved in the other publications and instances of prior use to which you have referred in your deposition. Please notice that for the purpose of shortening the cross-examination I ask you only to state the points of difference and I do not ask you to recite such matters as there may be in common with all of these operations.

DEFENDANT'S COUNSEL: The question is objected to on account of the indefiniteness of "the other publications and instances of prior use to which you have referred in your deposition." Does counsel intend that the witness shall review his entire deposition and every anticipation referred to therein? It is submitted that he should make the question definite and point out the patents, publications, and prior uses with which the Terre Noire use is to be compared.

A. Without going into small and immaterial details, I would say that — the Terre Noire operation, which is the typical and fundamental mixing operation, a converter charge is at Terre Noire taken one-half from each of two furnaces and in the language of Mr. Kohn "in this way the Terre Noire Company always obtain a mixture of the metals and the greatest regularity is secured through the work." The ladles are filled by runners in front of the blast furnace, carrying the iron from the furnace to the ladle. I will take my testimony and take each example of mixing molten pig metal as it comes, but it is proper to say that the method of Terre Noire has been in use with foundry cupolas doubtless from the earliest history of foundry practice. The Terre Noire method was in use in
608 a refining process, and for mixing metals taken directly from the smelting furnace. The ordinary foundry practice alluded to in testimony of Mr. Cupples and in Kirk on "Founding of metals" differs from the Terre Noire in using generally a single cupola and in mixing successive taps from the same cupola. It also differs in that there is frequently a remainder in the ladle after metal has been poured from it for foundry use to which the additional tappings are added from time to time. The foundry use in evidence as to car-wheel works shows the mixing, both of irons from two or three cupolas with each other and with previous tap. This retention of the metal in the charging ladles does not occur in the Terre Noire practice so far as it is described. The evidence as to mixing of irons, molten irons, from two or three air furnaces at Fort Pitt, shows substantially the same mixing as at the Terre Noire, with the difference that the iron is both received into the mixing reservoir and discharged from it at the same time. This is an operation of continuous mixing, differing from the Terre Noire in the respect that the entire furnace charges are not received and retained in a reservoir sufficient to hold them all before the discharging operation is commenced. The mixing of crucible steel in a pool described as practiced in Russia is very similar to the Fort Pitt practice and has the same differences to the Terre Noire method, with the exception that the metals mixed are steels instead of pig iron. The Fulton Foundry method is the same method of mixing as at Terre Noire, the materials being obtained from air and cupola melting furnaces instead of smelting furnaces. The Bessemer ladle (English patent 566), of 1869, in an intermediate reservoir between cupolas and converters. If entirely emptied after tapping the converter charge out of it the method of mixing is the same as that at Terre Noire, the material being cupola-melted instead of direct. The Durfee methods of 1871 and '72 propose rever-

beratory furnaces by preference gas furnaces into which furnaces the crude iron as it is brought from the blast furnaces may
609 be poured and wherein it may be so mixed with other iron and be so treated as to insure the metal from time to time tapped out for conversion being as nearly as practicable of a uniform character.

Mr. BAKEWELL (interrupted): I do not want to waste time and as the answer which you give does not directly meet the point which I had in mind in asking the question, I will endeavor to be more specific and will reframe the question thus:

X Q. 96. Is there anything in the Terre Noire practice as described in the publications or patents, which is peculiar to that practice and which is not found in any of the others?

A. The Terre Noire operation is the typical and fundamental mixing operation of bringing together two portions of molten metal from different sources into a common ladle. In this case the molten metal is directly from the blast furnaces and is used in the Bessemer refining process. The other methods of mixing involve either more elements or portions from more numerous sources or some variation in the operation such as allowing a portion of the mixed metal to remain in the ladle as an element or portion to which portions of metal in molten state from other sources of supply are added. I would say that the method of the Terre Noire practice is the basis of molten metal mixing practice and is found in all the other variations mentioned in my testimony. If the Terre Noire practice were subject to an existing patent, I would say that all other mixing operations would be tributary to it. There is nothing in the Terre Noire method of mixing which is not found in any of the others.

All except the last sentence of the answer is objected to by complainant's counsel as not responsive.

Defendant's counsel submits to the court whether the entire answer is not responsive and a fair statement of the differences asked for.

610 X Q. 97. Which of the prior patents and publications to which you have referred describes specifically and in terms the method recited in the second claim of the patent in suit?

A. Taking the examples in order, I would say that Kirk on "Founding of Metals" so describes the use of the ladle in front of cupola. This publication describes a large ladle set in front of cupola so that the iron can run into it from the cupola and be poured out into the smaller ladles at the same time. This includes the introducing into mixing receptacle successive portions of molten metal which Mr. Kirk has described in the previous portion of the article as liable to vary in character. The purpose of the large ladle is to give the different brands of iron a chance to mix. Portions of the contents are removed from the receptacle from time to time, and I think it is evident that the ladle would not be entirely drained until the cupola melt and the foundry work for the day

was finished. This I consider embraces the method of the second claim.

(Counsel for complainant suggests that as the witness has already gone a considerable length in his direct examination to an explanation of his reasons, the same might be omitted in answer to this question, especially as they are not asked for, the question merely requiring a list of the publications and patents which in the witness' opinion specifically and in terms describe the method of the second claim. It does not call for statement — reasons or arguments. The witness is asked to observe this instruction in answering the question.)

Defendant's counsel calls attention to the fact that the question is changed by the above statement and that the answer commenced by the witness and interrupted by complainant's counsel was a perfectly proper answer to the question given.

611 A. Noting that the question excludes publications addressed to experts and which convey meanings to them, I would ask if I am required to define the method in terms without such knowledge.

By Mr. BAKEWELL: Please first give a list of such in your judgment described the same in terms, in language which would be recognized by persons unskilled in the art, and follow that by a list of such as in your opinion describe the same in language which would be recognized as such by the skilled steel-maker.

Adjourned until Monday morning at 10.30.

Met pursuant to adjournment, January 25th, 1897, at 10.30 a. m. Present: Counsel as before.

JOSEPH MORGAN, JR.—Cross-examination continued:

A. Ordinary foundry practice as in Kirk's "Founding of Metals;" Fort Pitt gun foundry, Rodman report; Altoona car-wheel foundry; Holley descriptions of cupola ladle used in London Engineering, 1873; Holley description of cupola ladles at Vulcan works, 1877; Holley report on direct metal, 1877; add to above for skilled steel worker Bessemer English patent 566 of 1869; Durfee U. S. patents of 1871; Deighton English patent, No. 3672, of 1873; Snelus discussion, 1874; Durfee letter, 1874; Hunt's history, 1876; Bessemer discussion, 1876; Snelus on Fritz, 1878; Witherow United States patents, 1885.

X Q. 98. What advantages would you gain by adopting in 1895 the practice of supplying converters of defendant's works with metal which had not been remelted after being taken from the blast furnace, instead of your former practice of supplying the same solely with pig metal which had been remelted in cupolas?

DEFENDANT'S COUNSEL: Objected to as irrelevant and immaterial, in view of the description of the use of direct metal prior to patent in suit.

612 A. In supplying the converters with direct metal, either with or without the use of an intermediate reservoir, there is a saving of cupola fuel, labor and expenses, which is effected if the entire supply to converting works is direct metal. If part of the supply is direct metal, there may be a partial saving of cupola remelting cost. Both of these savings are subject to correction for the somewhat increased expense of longer blowing and more irregular work, which is noticeable either with or without reservoir in direct work.

X Q. 99. Was it for the purpose of obtaining these advantages that the apparatus of which you have spoken was installed in 1885 at the defendant's works?

A. The apparatus you refer to was installed by direction of Mr. D. J. Morrell, general manager, who fancied it would be some advantage to us at that time in affecting above saving.

X Q. 100. How long have you known of the various publications which you have mentioned in your direct testimony or the substance of them, or any of them?

A. This is difficult to say. I have no distinct recollections as to some of them. You will notice that I was not employed in steel works until 1879. Publications preceding that date I may or may not have read until within the last two years. I have been a reader of London Engineering and reports of the Iron and Steel Institute and the American Institute of Mining Engineers before and since that date. My special examination of this literature has been most thorough within the last two or three years.

X Q. 101. When did you first know the substance of the papers of Mr. Holley?

A. Mr. Holley's general papers I probably read in the publications in London Engineering, Mining Engineers' Proceedings and other places about as issued. His special reports to his clients and to the Bessemer Steel Patents Co. and its predecessor, I received after my appointment as chief engineer, about 1881, of the Cambria
613 works. Some of the preceding reports I saw while working as assistant engineer or draughtsman at Cambria works from 1879 to 1881. The '77 Holley report doubtless went to my predecessor, Chief Engineer D. N. Jones, and was not transmitted to me. Mr. Holley's report of 1881 and posthumous report of 1882, not in evidence, are the ones I refer to as having received personally after 1881. The general manager's records and office fixtures were destroyed by the flood of 1889 at Johnstown. Mr. D. J. Morrell, during his lifetime, was in the habit of corresponding with Mr. Holley and the record is now destroyed.

X Q. 102. Is it a fact that within the last few years you undertook the search of the prior publications for the purpose of getting a defense against an expected suit on the Jones patent here in suit?

A. Before deciding to put in a reservoir we reviewed the whole state of the art as to patents and publications.

X Q. 103. Was not the Carnegie Steel Company the first steel-manufacturing concern in this country to install and use for sup-

plying metal to converters a receiving and mixing vessel (other than a ladle, receiving metal drawn directly from the runner of the blast furnaces)?

A. Understanding your question, to limit the receiving vessel to direct metal, I believe they were.

X Q. 104. In reviewing the prior state of the art in the manner mentioned in your answer to X Q. 102, did you have in mind question of obtaining a defense against the Jones patent here in suit?

A. Yes; we reviewed the whole subject, as is our custom before undertaking expensive improvements, to determine whether it were possible to use a reservoir as suggested by Mr. Snelus and others, and for this purpose examined the Jones, Witherow and other patents, and also the prior state of the art in regard to reservoir ladles long in use at steel works to determine whether there would be any change of function in a reservoir intermediate between blast
614 furnaces and converters different from a reservoir between cupolas and converters.

X Q. 105. Please state when this examination was made.

A. I do not recall the exact date, probably some time in 1894, about the time our general manager decided that our blast furnaces were sufficiently complete for direct work.

X Q. 106. Had you at that time seen the Jones mixing apparatus at the complainant's works?

A. I have already so stated.

X Q. 107. In the defendant's works from how many blast furnaces is the molten metal for the mixer obtained, and what is the average weight of the cast of metal from each furnace?

A. From about four furnaces; owing to restricted production of works we had not used more than this, and sometimes less. Tappings varied considerably in size, say from two to four ladles, weights varying from 20,000 to 40,000 pounds of molten metal per ladle and varying greatly with the furnace. Two of our furnaces having recently been remodeled are making a very much larger production than a year or two ago. The number of taps also varies, depending on condition of furnace, so it is impossible to give an exact answer to your question.

X Q. 108. Is it not a fact that the experimental receiver which you erected at the defendant's works recently and which has been testified to by the witness Thackray, contained only 75 tons, and would have been filled or nearly filled, if a single full cast from one of your furnaces had been run into it?

DEFENDANT'S COUNSEL: Objected to as immaterial.

A. That is so.

Adjourned here until 2.30 p. m.

615 X Q. 109. For how long did the experimental work with the mixer mentioned in my last question continue; for how many days or weeks?

A. Three and three-quarter days.

X Q. 110. Do you mean to say that this was the full extent of the experimental experiments with that mixer?

A. Yes.

X Q. 111. Was it not run for a longer time?

A. Not at that time.

X Q. 112. I have not limited my questions to any particular period, and will you now answer question 109 again, answering it fully?

A. We made a preliminary test of some days in which the data was improperly kept and is therefore worthless.

X Q. 113. How long was this?

A. I think about three days.

X Q. 114. Was this all?

A. That was all. I may add that neither myself nor Mr. Thackray made the preceding test and the results were not in such shape that any examination could be made of them.

X Q. 115. Now, Mr. Morgan, is it not a fact that this experimental mixer was operated through a period of about three weeks? Or that the experiments with the mixer extended over a period of three weeks?

A. Not a fact at all. My answers are correct.

X Q. 116. You know all the experiments that were made with that mixer, do you?

A. I believe I do. I was not personally present any great length of time at either experiment, but know of no other.

X Q. 117. To whom were the accounts of the unsatisfactory parts of the experiments of this mixer made besides yourself?

616 DEFENDANT'S COUNSEL: Question objected to as an improper statement, the witness's statement being that "the data was improperly kept and is therefore worthless."

A. Mr. Thackray and myself examined the records and possibly Mr. Price saw them. I do not know of anybody else except the observer himself, Mr. Cabot.

X Q. 118. Isn't it a fact that when this apparatus was used a skull was formed in it which had to be removed?

A. There was considerable difficulty with skull in the entering trough which was of considerable length and made a bend. We rearranged the railroad track so that the ladle poured directly into the reservoir and obviated this difficulty. There was no considerable skull in the vessel itself, the difficulty being in the trough arrangements. I had forgotten this point of the first test which led to a good deal of delay in getting the iron in.

X Q. 119. Was trouble not experienced in keeping the metal hot in the vessel?

A. No considerable difficulty in keeping the metal hot, although the process of handling the ladle to the experimental receiver was slow and unfavorable.

X Q. 120. What means did you use to supplement the heat in the vessel?

A. We used the same type of oil jet that us use in our large receiver.

X Q. 121. Do you mean that in the practical operation of your commercial mixer you keep a constant oil flame burning inside the same?

A. That is our practice, and I believe the use of the flame is constant.

X Q. 122. For how long has that been so?

A. From the beginning of its use, following the practice at Sparrows Point and also I believe at South Chicago.

X Q. 123. Is it not a fact that at the end of the experiments, or one of them, the men in charge could not stop the tapping
617 hole so that the metal running out filled the ladle, ran over onto the tracks, drained the vessel, so that it took some time to clean up, and by that time the metal in the ladle was too chilled to pour?

A. I believe we had such an accident in the first test, owing to the large size of the tapping hole. I did not see the accident, as it happened at night.

X Q. 124. And is there not a solid ladle skull of about 35,000 pounds lying there still as the result of this; or, if not, when was it removed?

A. I have no recollection of its lying there still, and no knowledge of when it was removed.

X Q. 125. Before pouring the metal into this experimental vessel, the graphite was carefully skimmed from the surfaces, was it not?

A. My recollection is quite to the contrary. In our large or commercial receiver, as you term it, we skimmed the graphite regularly. In this test, owing to the difficulty resulting from location my impression is the graphite was not skimmed.

X Q. 126. In or during the final experiment or the experiment which you have reported, was there not trouble in stopping the flow of the iron?

A. I think none whatever.

X Q. 127. And are you sure of this?

A. I am quite sure of it. I was not present myself, except a short time in the daytime. I heard of no difficulty at all.

X Q. 128. What then was the reason for the great variation in some of the weights reported to have been tapped out from the vessel?

A. The variation probably arose from the variable weight of the iron already in the ladle, some being probably taken to fill the same, either from cupolas or other mixer or reservoir.

618 X Q. 129. Do you mean by the word "probably" that this statement is not based on your own certain knowledge?

A. No. I mean that it must have been so taken, as the amount run through the experimental receiver was not sufficient to keep the large plant running, and part of the iron was taken from other sources at times, more or less in amount, as the necessities of the work required.

X Q. 130. Why is it necessary to use an oil burner in the defendant's mixer and not in the mixer of the complainant, and is it necessary in the case of the defendant's mixer?

A. I can only give a theoretical explanation as to the Edgar Thomson apparatus, which is, that owing to its small size relative to the quantity of metal worked through it, it receives constant accessions of initial heat. So far as our own practice goes, we have always considered it necessary. A burner is applied in the pouring spout, and tends to keep the pouring spout free. Possibly owing to our large size of reservoir relative to the quantity we have so far used in it a burner is necessary here.

X Q. 131. How long in the practice of the defendant's works do you continue to use the mixer? Do you stop and clean it out at the end of each day's run, or do you continue to use it throughout the heat, from day to day, without stopping?

A. We use it throughout the week without stop.

X Q. 132. In the operation of the experimental apparatus tried by Thackray, is it not a fact that you did not run the metal into the vessel directly in troughs from the blast furnaces as shown in the Deighton patent, but that the metal was received in ladles at the blast furnaces and thence poured into the vessel? Is it not a fact also that the top or cover of your experimental vessel was made removable?

DEFENDANT'S COUNSEL: Objected to as immaterial.

619 A. In the operation of the experimental apparatus we did not run the metal into troughs at the blast furnaces and carry it directly to the receiver as shown in the Deighton patent, but followed the method suggested by Mr. Durfee in his patents of 1871. The metal was carried in ladles from blast furnaces, raised on a hoist, and poured into the apparatus. The top of the experimental vessel was so that it could be removed as a matter of convenient construction. It was not removed, to my knowledge, during the experiment.

X Q. 133. Will you please mark with the letter "Z" on the drawing of defendant's plant the track upon which the ladles charged with molten iron stand before they are lifted on the hoist and discharged into the mixer.

A. The ladles are run on track "Z" across the hoist to the right-hand side thereof. The ladle which it is desired to hoist being left on the platform of the hoist.

X Q. 134. As a general rule, are there standing by the hoist several ladles full of metal ready to be hoisted and discharged into the mixer in their turn and several empties, or what is the general fact in this regard?

A. The ladles are brought in train from blast furnace and those of each tap are run upon the track "Z" and hoisted in succession. The empty ladle coming down is switched off to track "Y," and there cleaned. When all the ladles are empty they are taken to furnace or stopped at the repair-house, as may be necessary.

X Q. 135. Will the hoist lift more than one ladle at a time?

A. No. I have already stated, the ladles are hoisted in succession, and I mean, one at a time.

X Q. 136. Why is it that you have spoken of Thackray's experimental apparatus as an experimental receiver, whereas in the tracing which has been put in evidence it is called an experimental mixer?

A. For the reason that I presume I have liberty to choose my words in giving my answers.

620 X Q. 137. What is the difference between a smelting furnace and a melting furnace, as used in the metallurgy of iron?

A. Webster defines "smelting furnace" as a furnace for reducing ore. A melting furnace is a furnace for reducing materials to a molten condition and would include cupola or the ordinary air melting furnace or furnaces of that type.

X Q. 138. Then according to that definition a blast furnace is a smelting furnace and a cupola furnace is not a smelting furnace? Is that correct?

A. I so understand it.

X Q. 139. You have spoken in your testimony somewhere of one David Evans, being manager of the Rhymney works during 1877 and 1878. Do you understand that this Mr. Evans is the same as the one who has given testimony in this case on behalf of the complainant?

A. I take the information from testimony of Mr. David Evans in this case.

X Q. 140. In which of the publications or patents or instances of prior use referred to in your direct testimony do you find described or practiced the following series of operation:

The tapping of several blast furnaces into ladles, whereby the tapping from each furnace is subdivided prior to its mixing, the transfer of these ladles to a mixing vessel (which is not a reverberatory furnace) in which mixing vessel a large body of molten metal is continuously maintained; the successive withdrawing of ladles full of metal from said vessel for further treatment, and the continued replenishing of the vessel by pouring in from the ladles first above named successive portions of the molten metal.

DEFENDANT'S COUNSEL: Objected to as immaterial, first for that the question does not define any invention in accordance with any claim under which the defendant is sued; and second, for
621 that it appears by testimony of witnesses for complainant herein *in* certain of the steps enumerated in the question *of* not of the essence of the invention claimed; third, for that the steps stated in the question do not constitute a specific process described in the claim of the patent in suit.

A. I would ask for a definition of the reverberatory furnace as meant in this question.

By Mr. BAKEWELL: Please define it yourself in the sense in which you ordinarily understand the term, and I will then tell you if you may use such definition in answering the question.

A. As to definition of what may be included in reverberatory furnace, I would say that the Jones apparatus is a furnace of such a type, being heated by internal combustion of fuel and being covered with a reverberatory roof, a fact that at times fuel may be unnecessary does not eliminate it from this class in my judgment.

X Q. 141. Your definition of the reverberatory furnace is much broader than any definition which has ever been suggested to me, but without going into an analysis of it, which is aside from my present purpose, you may answer the question, taking as the meaning of reverberatory furnace, a furnace having a combustion chamber at one end, a chimney at the other end, an intermediate hearth on which metal is adapted to be melted and a roof above the hearth adapted to reverberate or throw down upon the hearth off that continually passing flame.

A. The apparatus in patent in suit is, I believe, heated by natural gas and has sufficient outlets to serve as a chimney. I therefore still think that a reverberatory furnace is shown in the patent in suit. The description of the operation in the question I will take up, as follows: Tapping of several blast furnaces into ladles. This eliminates the Deighton patent from the process as Mr. Deighton shows runners, although ladles had long been used for the
622 same purpose. It also eliminates Mr. Snelus' description, possibly, as the size of blast-furnace taps at the dates of his suggestion were about sufficient to fill one ladle. However, Mr. Snelus does not limit his suggestion by defining the number of ladles to be used for this purpose, nor does Mr. Holley in his description in his report of 1877, and I therefore am unable to find a specific mention of the transfer of the heat or tap in several ladles, it probably not occurring to Mr. Holley that such details need be mentioned to the parties whom he was instructing. Assuming that the transfer in the case of the Snelus suggestion or the Moss Bay vessel may well have been in two ladles dividing the tap, I would say that to a skilled steel-worker the Snelus suggestion, which simply involved a large ladle or the Holley suggestion of a large furnace or reservoir, which he further said need have very little gas upon it to keep the molten metal hot, and in which I presume the flame could have been reduced to nothing if the condition of molten metal permitted it, both convey to my mind the operation in question. The words in which "mixing vessel a large body of molten metal is continuously maintained, the successive withdrawing of ladlesful of metal from said vessel for further treatment and the continuous replenishing of the vessel by pouring in from the ladle first named," are, considering the state of the art, and the well-known use of ladles between cupolas and converters fully covered by Mr. Holly's word- "storage of a large quantity of iron in a reverberatory furnace or other reservoir." In both Mr. Snelus' and Mr. Holley's suggested apparatus the reservoir may be an ordinary ladle. If provided with a cover, but without fuel, it would under Mr. Bakewell's definition not be a reverberatory furnace. Mr. Holley's terms cover either the case of an ordinary ladle, a covered vessel or a fur-

nace. I am therefore clear that the operation you describe with its limitations of immaterial details is still covered by the suggestion of Mr. Snelus and the Holley report. I may also add that the words Mr. Holley uses in describing Mr. Snelus' storage ladle,
623 namely, "to store, mix and pour," do considering the state of the art and the knowledge of the use of the intermediate ladle or reservoir certainly convey to a skilled metallurgist the operation in question. My explanation in direct testimony of the known proper use of a reservoir certainly convey the whole process or method of the Jones second claim, if such is intended to be defined by the question.

Adjourned to tomorrow morning, January 26th, 1897, at 10.30 a. m.

Met pursuant to adjournment, January 26th, 1897, at 10.30 a. m. Present: Counsel as before.

Cross-examination of JOSEPH MORGAN, JR., continued:

X Q. 142. In which of the prior publications or prior patents or instances of prior use referred to in your direct testimony, do you find described or practiced the following series of operations: Tapping several furnaces, the tapping of each being divided into portions prior to the mixing operation, transferring said portions to a mixing vessel (which is not a reverberatory furnace) in which mixing vessel a large body of molten metal is continuously maintained; successively withdrawing portions only of the contents of said mixing vessel; and continually replenishing said vessel by pouring thereinto successively the portions into which the tapping of each furnace was divided as above stated?

DEFENDANT'S COUNSEL: Objected to as immaterial for that the question does not define properly or accurately the subject-matter involved in the issue in this cause.

For the purpose of economizing time counsel for defendant at this point requests counsel for complainant to state whether it is his intention at the hearing of this cause to insist upon infringement of both claims in the patent in suit, and, if not, upon which claim.

624 This request being made in view of the last question and others preceding.

By COMPLAINANT'S COUNSEL: We insist on infringement of both claims.

A. I cannot point out such references, as I think the conditions of the question as to principal apparatus, auxiliary small appliances and method of operation exclude all patents and publications in evidence, including the Jones apparatus and both claims of the patent in suit.

X Q. 143. Are you interested in the defendant company?

A. I think I incidentally mentioned in conversation here yesterday that I had a few shares of stock in the Cambria Iron Company.

Redirect examination by Mr. DODGE:

R. D. Q. 144. At Cambria was it the practice to empty the successive ladles of metal from the blast furnace, forming parts of one cast, into the mixer?

A. It was.

R. D. Q. 145. Then you had in the mixer from the several ladles the same elements that you would have had if the metal had been directly run by a spout from the blast furnace to the mixer. Is that correct?

COMPLAINANT'S COUNSEL: Objected to as leading.

A. Precisely the same.

R. D. Q. 146. Why were ladles used at Cambria to convey the blast-furnace metal to the mixer? Was it because of any supposed effect on the mixing?

A. They were used because they were a convenient and well-known apparatus; they had no effect on the mixing whatever.

R. D. Q. 147. You have been cross-examined as to your reasons for calling the Cambria vessel or mixer a reservoir. You may give any additional authority that occurs to you for the use of
625 that name and you may say whether or not the patentee, Jones, has authorized this name for the vessel.

A. I used the term applied to the cupola ladle by Mr. Holley in 1877 in his article on the cupola plant at the Vulcan works. He also used the term in his report upon the use of direct metal in a way which made the function of the apparatus plain even to the unskilled. In his article on the Vulcan works he says, speaking of the cupola ladles, "they form resorvoirs which make the melting department and converting department independent of each other within limits. This advantage was not fully appreciated until the large production of the last few years were attempted." In my opinion, in view of the most remarkable advances in production of converting works since Mr. Holley's articles were written, the term is the most apt and fitting description of an intermediate vessel, especially when such vessel is intermediate between blast furnaces and converters the furnaces making productions scarce dreamed of in Mr. Holley's time. I will recite from the record various terms applied to the intermediate vessel as descriptive, namely, ladles or receivers, interposed ladles, reservoirs, intermediate or accumulating ladles. The term "reservoir" is used in the Jones method patent and several times in the Jones apparatus patent, No. 404,415.

R. D. Q. 148. You were questioned as to a visit to Mr. Gayley at the Edgar Thomson works before the reservoir was installed at the Cambria works. Did you, before such installation, visit any other Bessemer works to examine their metal reservoirs or mixers?

A. Yes. I and others on the works' staff visited South Chicago, Cleveland and Sparrows Point at various times pending the installation of the reservoir.

R. D. Q. 149. What was your purpose in visiting the Edgar Thomson works and those other works pending the installation of the reservoir?

A. To exchange views as to the operation and type of apparatus in accordance with the usual courtesies extended to our
626 practical managers by other works and always reciprocated by ourselves.

R. D. Q. 150. Was there any custom among superintendents and engineers of Bessemer works of visiting the different works obtaining information as to apparatus or operations, and if so, how long had such custom existed to your knowledge?

A. It has been quite a common custom from the beginning of Bessemer operations in America, a number of the large works being stockholders in common in the Bessemer Steel Patents Company.

R. D. Q. 151. State, if you know, the general purpose for which this Bessemer Steel Patents Company was formed?

COMPLAINANT'S COUNSEL: Question is objected to as foreign to any of the issues of this case; and because it does not appear that the witness was personally conversant with the organization of this company or with the purposes of its organization.

A. I understand the purpose is the common ownership of some patents relating to Bessemer and kindred operations.

R. D. Q. 152. Did Mr. James Gayley while he was superintendent of the Edgar Thomson works ever visit the works of the Cambria Iron Company for the purposes such as stated in your answer No. 149, and if so, how often did he make such visits?

A. Since Mr. Gayley has been superintendent of the Edgar Thomson furnaces or works I believe he has visited us several times presumably for the purpose of obtaining information. I cannot answer as to the number of visits. My recollection is not clear.

R. D. Q. 153. When you visited the Edgar Thomson works as referred to in cross-questions No. 37 to No. 40, was there any conversation between you in regard to patents covering the mixer or reservoir?

627 A. I think it likely there was not. Mr. Gayley does not so state, and I had no authority to broach the subject of patents, my duties being simply with construction and operations of apparatus.

R. D. Q. 154. What is the general construction of the reservoir of the Maryland Steel Company at Sparrows Point and compare the same with that of the Cambria Iron Company?

A. Both are semi-cylinders lying with axis horizontal, with convex ends and with slightly arched roof; provided with receiving and discharging spouts, resting upon roller beds and rotating upon the horizontal axis of the cylinder without raising or falling motion of this axis. They differ slightly in mechanical details and in size, and in size they differ very largely.

R. D. Q. 155. Please also give a general description of the reservoirs at South Chicago and Cleveland Rolling Mill Company in Cleveland.

A. The two reservoirs at South Chicago are complete cylinders, with slightly convex ends, and rest upon fixed rollers, upon which they rotate about the horizontal axis of the cylinder. The reservoirs

at Bessemer plants of the Cleveland Rolling Mill Company are of Aiken design similar to that of Cambria except being of a smaller size. Like the reservoir at Cambria, they have Aiken patented details.

R. D. Q. 156. Where are the metal reservoirs or mixers of the Maryland Steel Company, South Chicago Works and Cleveland Rolling Mill Company located with relation to the converters?

A. The Sparrows Point reservoirs are located in an extension of the converting house, quite close to same, and as I recollect, the charging ladle runs upon a low level track to receive metal either from cupolas or receivers and after being filled is run upon a lift, carrying it to converter floor. The reservoirs of the South Chicago works are located in a separate building close to converting
628 house, and the location of the Cleveland Rolling Mill Company's reservoirs may be described in a similar way to that of South Chicago.

R. D. Q. 157. In referring to your answer No. 46 to exposure of surface for a given quantity of metal, in vessels of different form, did you refer to top surface of metal or to entire exposure?

A. The term "exposed surface" was intended to include the top surface of metal and the bottom, sides and ends of reservoir. The surface in which the metal is contained being also cooling surface and transmitting heat to the external radiating surface of vessel.

R. D. — 158. Will you now please compare the exposed surface of the semi-cylindrical Aiken apparatus and that of the elongated rectangular apparatus shown in the Jones patent in suit for given quantity of metal contained? I do not mean by this accurate measurement of scale, as you probably have not the instruments for measurement here, but general measurement such as will show proportions of exposed surface.

A. To make the subject plain, I would say that in my answer to question No. 46 comparing the Jones with the Aiken apparatus I neglected to explain that the bath contained in the Jones apparatus is triangular when the vessel is in normal position, for pouring. Portion of the bath at the apex of the wedge-shaped fluid contents are shown in the drawing of the patent as running to an edge. When such a shape is compared in ratio of content to surface exposed, the result is not so favorable for avoiding heat loss as in the more compact shapes cited by Mr. Bakewell in cross-question 56. My neglect to define my answer in cross-question 46 led to a misunderstanding. Taking dimensions given in cross-question No. 56, the ratio of surface divided by content is for a semi-cylinder 86 hundredths; for a semi-cube 80 hundredths and for a wedge-shaped vessel with base 10 feet perpendicular, 7½ feet giving approximately the same content as that of the semi-cylinder, the ratio of
629 surface divided by content is one (1) approximately showing the inferiority of the wedge-shaped solid.

Adjourned here until 2 00 p. m.

R. D. Q. 159. I call your attention to cross-question 75 and answer

thereto. I do not understand what meaning you intend to convey. Will you please explain it?

A. My meaning is that molten pig metal can be obtained either directly from a blast furnace or from cupola or other melting furnaces.

R. D. Q. 160. So far as the mixing of crude molten metal is concerned, is there any difference so far as the principle or process of mixing is involved, whether molten metal is poured into a vessel containing a body of metal remaining after pouring a charge from that vessel, or the molten metal is poured into a body of metal just previously introduced into the vessel.

A. There is no difference in the principle in the operation. The remainder represents one portion of the several portions which are mingled in the mixing process.

R. D. Q. 161. Reference is made in the cross-examination to preparations having been made about 1885 or 1886, which was prior to the invention of the patent in suit, to the use of direct metal in the Cambria works. Can you state why the Cambria Company did not then proceed to the use of direct metal?

COMPLAINANT'S COUNSEL: Question objected to as incompetent, it not being shown what were the witness' grounds of knowledge on this point.

DEFENDANT'S COUNSEL: The witness may state his grounds of knowledge in answering the question.

A. The grounds of my knowledge are that the apparatus was installed by me under direction of General Manager D. J.
630 Morrell. My recollection is that we had a number of improvements on hand at this time, that the progress of this improvement in question was slow, and that during that time the judgment of the management had so far changed that it was considered our Bessemer plant needed reconstruction. Also that the blast-furnace plant had not yet reached such condition that the use of direct metal was then desirable. This condition of affairs continued as to the Bessemer plant until about 1890, and we have been making additions to our blast-furnace plant to perfect it up to this time.

R. D. Q. 162. Please state generally the improvements which had been made in your blast-furnace plant which made it practicable to use the blast-furnace metal from the converters without remelting.

COMPLAINANT'S COUNSEL: Question is objected to because it is leading, and that it assumes a state of facts not proven by the witness's testimony.

A. The practicability to use such metal depended upon a sufficient supply at the main works. As stated in cross-examination, in 1880, we had two large and four old furnaces. These old furnaces were torn down and rebuilt and completed about 1884. Their workings were not entirely satisfactory, and we proceeded by various changes of furnace lines, enlargement of steam cylinders, of 14 blowing engines, change of moving parts of same engine at subse-

quent date, and at still more recent date, replacement of all air cylinders of these engines, new stoves at one of our large furnaces, enlargement of hot blast stoves of five furnaces, some of which improvements are still in progress, so that in brief, our furnace production did not reach a point of sufficient supply for converting work until within the last year or two. Our greatest increases of furnace production having been made by changes of furnace lines within that time. Four of our furnaces are yet to be remodeled in this improved way.

631 R. D. Q. 163. Referring to the failure of the workmen to close the tapping hole in the experimental mixer at Cambria, was there anything peculiar in the method of closing that hole or in the character of the accident?

A. No; the method was the usual one in cupola practice, and so far as I am informed was due to carelessness or inexperience of the men with this apparatus. The position of the apparatus was inconvenient, and it did not give the men very good chance to work.

R. D. Q. 164. Referring to cross-questions Nos. 137 and 138, please now state how a blast furnace and a cupola furnace differ from each other in general construction and principle of operation?

A. The stack of a smelting furnace is often called a cupola, referring to its shape as that of a cylinder or barrel. It is so termed in some metallurgical books, but stack is the more common term in this country. Into this stack ore with suitable fluxes and fuel is introduced at the top. In the operation of the furnace the ore is reduced to a metallic state by the oxidizing action of carbon or gas containing carbon. This metallic iron melts in the lower part of the furnace taking up a proportion of carbon and other ingredients, dropping to the bottom of the hearth as molten pig iron. The earthy impurities combine with the flux, and are also melted and descend into the hearth resting upon the top of the molten pig metal. The molten pig metal is drawn from the hearth from time to time by tapping, and the molten impurities combined with the flux forming a cinder are also drawn from the hearth at a higher level.

A cupola melting furnace differs in its functions in that it is charged with solid pig metal and other irons in the shape of scrap, generally scrap steel in a Bessemer works. A proper proportion of fuel is also charged with sufficient flux to form a cinder with the impurities of the fuel, and sand upon the pig. This charge descending through the cupola is heated and melts in the lower

632 portion of the same near the hearth and dropping into it. The slag formed descends and molten materials, slag and molten pig iron, are tapped off from the hearth about as in blast-furnace practice. The smelting furnace and melting cupola differ in proportions of their lines forming the interior, but are similar in functions of furnishing molten metal, one from the ore and the other from pig metal. Both are supplied with blast under pressure, which furnishes the necessary oxygen for combustion of fuel.

R. D. Q. 165. When using either natural gas or oil as fuel in a reverberatory furnace, is it necessary or usual to have any combustion chamber other than the space above the metal on the hearth?

A. It is not necessary. In open-hearth furnaces we introduce oil vapor directly over the metal bath contained in the hearth. We also so introduced natural gas, and in the ordinary Siemans open-hearth furnace the air and gas first meet in the large chamber immediately over the metal bath. There is no combustion chamber so called in this type of furnace other than this mentioned.

R. D. Q. 166. Please examine the drawing of the Jones patent in suit, and state about what proportion of charge, which I understand is indicated by the dotted line in figure 1, would remain within the vessel when it is raised so that its forward end contacts with the rest or stock 14.

A. As a rough approximation I should say that with metal at the height shown in dotted line when mixer is in position of rest the metal which remains in the vessel when tipped to rest upon the stock 14 in the act of pouring is about one-third of the fluid contents shown by dotted line.

Recross-examination:

R. X Q. 167. Will you state whether, in your opinion, the addition of a cast of the blast furnace to the defendant's mixer in successive portions added one at a time does not tend to maintain
633 a more uniform temperature and composition, (or either) of the metal throughout the operation, with the advantages consequent thereon, than if each furnace cast or several furnace casts together were dumped into the mixer in a single mass. To give you a complete example of what I mean, does it not produce a more uniform temperature and composition, or either, to add successively to defendant's mixer the relatively small portion of the cast, namely, 20 tons or less, which the defendant introduces by the ladles, than if the whole cast of sixty to seventy-five tons were run in a single mass into the mixer at each replenishment thereof?

DEFENDANT'S COUNSEL: Objection after question 140 repeated.

A. Not necessarily. Our reservoir is very large and the ladles are dumped in rapid succession. It would be quite feasible to prolong the pouring of a whole cast from a single ladle to the time occupied in pouring three ladles.

R. X Q. 168. You have spoken of the Vulcan works at St. Louis in your discussion of the prior publications, was this works ever installed with apparatus for the use of metal direct from the blast furnace?

A. I cannot say as to this. I understand Mr. Holley's article to show the works as erected. The works were in operation. All of Mr. Holley's articles written in conjunction with Lenox Smith I understand showed existing works.

R. X Q. 169. How long has the mixing apparatus of the Cleveland rolling mill been in operation, and when was it constructed?

A. I think it was started in '95.

R. X Q. 170. When did you first see it?

A. I cannot say exactly when; my recollection is indistinct.

R. X Q. 171. Was it in 1895 or 1896 when you first saw it?

634 A. I think it was in 1895, as my impression is I visited there before our own plant was installed and have so stated.

R. X Q. 172. Referring to your 1885 apparatus, the fact is, is it not, that this apparatus was not provided with or then designed to be used with an intermediate storing and mixing vessel other than the ladles, but that it was designed to be used with ladles receiving the metal from the blast furnaces and carrying the same directly to the converters?

A. That is so.

R. X Q. 173. Your duties at defendant's works include the designing or supervision of designing of the defendant's apparatus?

A. Yes.

R. X Q. 174. Referring to what you have said concerning the visits of Mr. James Gayley to your works—has Mr. Gayley or any one of the complainants, officials, ever visited your works and questioned you about the operation of patented apparatus, the patents for which have been owned by your company, and then returned to his establishment and appropriated that apparatus without consent on your part or on the part of your company, and is this the custom or etiquette of steel manufacture?

A. I cannot say that he or they have and deny that we are using at the Cambria works any apparatus patented by the complainant.

R. X Q. 175. Is it not a fact that the apparatus of the defendant which in this deposition you call a reservoir is ordinarily and familiarly called a "mixer" in and about the defendant's works?

A. I think that may be a shop term.

R. X Q. 176. What is the ordinary daily tonnage of metal which passes through the defendant's mixer?

635 A. Owing to business depression our work has been exceedingly irregular, involving weeks of stoppage and some weeks in which cupolas only were used. Without examining the works' book I could scarcely give you more than an approximation. The total works' tonnage, both of direct and cupola metal, I would say does not exceed 20,000 tons per month.

R. X Q. 177. What is the daily blast-furnace production?

A. That also is changing so rapidly that I cannot give any correct approximation. At the present time we have two furnaces out of blast, I believe. It must also be remembered that of the blast-furnace production part is spiegel or ferromanganese and part is metal for the open-hearth work, so that the daily production does not all go to Bessemer plant. My impression is that we are now making from a thousand to twelve hundred tons per day in our blast furnaces.

R. X Q. 178. Will you please produce a blue-print drawing from the defendant's record of drawings showing the form of open-hearth reverberatory furnace used by the defendant which you believe most nearly of all your furnaces to resemble the Jones mixer? I

want the blue print to be made from an original tracing of a furnace now in use.

Defendant's counsel notes on the record under the order of court the testimony in the cause is required to be closed today; that it is impossible to have the drawings produced at the present time, because the testimony is being taken at Lakewood, N. J., while he presumes the drawings referred to are in Johnstown, Pa.; that while he has no objection to the drawing being produced in the future, he does not see how it can be done without the right being reserved to examine this or other witnesses as to the drawing when it is produced. The matter has been developed entirely in connection with the cross-examination in the case which was only closed by complainant this morning and that witness Morgan in connection with his answer to No. 140, as given yesterday when
636 under cross-examination pointed out what he understood to be a reverberatory furnace, and it is believed if it was intended to make the request it should have been made then so that an attempt could have been made to produce the drawing today.

By COMPLAINANT'S COUNSEL: The question is obviously proper recross. See R. D. Q. 165. Let the witness file the drawing with the clerk in Pittsburgh within a week. If defendant's counsel wish to redirect on this point, let them now consult the witness in private and then do so.

Defendant's counsel answers that it is obviously impossible to take the course suggested by complainant's counsel; that it is not to be presumed that any witness can describe from memory the thing called for by the question and select from the drawings of the works of the defendant what is there called for and give a verbal description of it considering the size of the works and the variety of furnaces therein and considering the length of time for which they have been in operation.

By COMPLAINANT'S COUNSEL: The witness then should not have answered R. D. Q. 165 and it ought to be withdrawn.

Defendant's counsel answers that there is no reason to withdraw the question whatever, that it is perfectly proper in view of the cross-examination; that as before stated no objection is made at all to the production of the drawing provided it is understood that defendant's counsel, who has not seen the drawing and knows nothing of it, reserves the right to examine this or other witnesses regarding it.

By COMPLAINANT'S COUNSEL: I do not so understand.

Defendant's counsel states that he will produce the drawing as soon as it is practicable for the witness to see to the production of the same, reserving the right as above stated to examine this or other witnesses in regard to it. He is informed by the witness that he is under orders from his physician to remain here for a month.

637 By COMPLAINANT'S COUNSEL: You will understand, however, that I do not consent to your right to examine the witness on this point after today.

R. C. Q. 179. In order that I may understand your statement concerning the reasons upon which you have acted in not putting into use the direct-metal apparatus which you installed in 1885, will you please furnish with the drawing for which I ask in the last question a statement compiled from the records of the defendant company showing for each year from 1885 to 1895, both inclusive, the number of blast furnaces in blast at the defendant's Johnstown works and the production of pig metal in each year, also the production of Bessemer ingots at the defendant's Johnstown works during the same period? I ask this question in order that I may know precisely the ratio of pig metal produced at the Johnstown works to the pig metal converted at said works into steel during each year of the period above mentioned.

Defendant's counsel, Mr. Kay, says that he does not know whether the witness has such access to the records of the company as will enable him to produce the information called for in the question, or whether such records have been kept so that the information can be furnished; that he has no objection to having inquiry made for the same and will endeavor to produce such records, reserving, however, the right to examine the present witness or others in regard to the same as part of the case.

By COMPLAINANT'S COUNSEL: In such case R. D. Q. 162 should not have been asked and ought to be withdrawn. Complainant's counsel cannot assent to the right of the defendant to examine other witnesses after this session.

Defendant's counsel answers that redirect question No. 162, as well as No. 161, grew out of cross-examination, and probably improper cross-examination, because it was in no way required in the direct; that the redirect questions were therefore entirely proper to
638 be asked, and the statement made in answers are evidently matters of the witness's own knowledge, while the information called for by the question is probably outside of his knowledge and matter of record entirely beyond his control; that as above stated, there is no objection to producing the information if it can be obtained subject to the right to examine witnesses on in regard to the same.

In answer to question 178 witness says that under instructions of counsel and subject to the reservation made he will endeavor to produce the drawing.

In answer to question 179 witness says there are received by him when at the works a rough statement of daily production. Not having any figures with me, I cannot furnish definite information upon the point you inquire about and have no record of furnaces in blast.

And under instructions of defendant's counsel and subject to the reservations made, he will endeavor to produce the information called for in the question.

By COMPLAINANT'S COUNSEL: It appearing from the testimony of the witness, Joseph Morgan, Jr., that the information given by the defendant and embodied in the stipulation printed on pages 97–98

of the record is in some respects at variance from the facts as explained by Mr. Morgan in this deposition, complainant's counsel hereby notifies defendant's counsel that in so far as the said variance appears the said stipulation will not be used by him at the hearing.

In answer to the above statement, defendant's counsel says that the stipulation was entered upon the record in the ordinary way and was given after the complainants had failed by two of the witnesses to prove infringement though information as to the operation of defendant's works had been freely offered to it that upon the making of the stipulation the witness Upton was closed without cross-examination and that he presumes that the court will hold this as all other stipulations in the case as binding.

639 As the defendants have acted upon this stipulation in good faith and have made their case in recognition of the same, and this notification is sprung upon defendant at the last moments of the closing of the case for the defense, he believes it only proper for the complainant's counsel to state in what respect he proposes to attack the stipulation, and ask him so to do.

By COMPLAINANT'S COUNSEL: I personally was not present at the making of the stipulation or admission, and am unable to reply to the statements of defendant's counsel otherwise than as the record will show for itself, and I object to the statement of the defendant's counsel if it is intended to be in addition to the record.

Complainant's counsel states that the said stipulation or admission in its statement "that the amount of molten metal in the mixer varies from nothing to its full capacity," would seem to create an implication as to the regular operation of the mixer, which does not accord with the testimony of Mr. Morgan, who says that the natural practice and the one which they follow is as in the operation of a water reservoir, to keep the same full as possible. The words which the witness used in his direct examination are as follows:

Begin with the words "Again, the obvious method," on page 44 M. S., and ending with the words "Using a reservoir anywhere," on page 45 M. S. If said stipulation is not intended to and will not be construed to mean anything different from this as the regular practice of the defendant's work, then, of course, I do not urge the present objection.

R. D. Q. 180. What is the fact as to the fluctuation, if any, in the quantity of metal in the mixer or reservoir in the ordinary Cambria practice?

COMPLAINANT'S COUNSEL: Objected to as having been already answered.

A. I believe our practice is to keep the reservoir well filled up. I am unable to give you the amount of fluctuation.

(Signed) JOS. MORGAN, JR.

640 *Stipulation.*

And now, to wit, January 22nd, 1897, it is hereby stipulated that the following statement of facts shall have the same force and effect as if the proper proof of the same was made either by witnesses or by documentary evidence, said facts being admitted by complainant's counsel, in order to expediate the closing of the case.

That the article heretofore offered in evidence and marked "Exhibit Holley 1877 Report" and entitled, No. 11, second series, "The direct use of blast-furnace metal in the Bessemer process," being an article by A. L. Holley, a printed copy of which has been offered in evidence as above set forth, and which was marked "Copyright, 1877, A. L. Holley," was duly copyrighted in accordance with the provisions of the statutes of the United States relating to copyrights; that the application for the copyright was received by the Librarian of Congress on June 23rd, 1877, and two printed copies of the said pamphlet were received by the Librarian of Congress on June 26th, 1877, said copies being duly stamped as received as of that date; and that a certificate of copyright was duly issued to said A. L. Holley as No. 7361 H of the year 1877, the above date of the application and the date of the receipt of the two copies of the pamphlet appearing upon said certificate. That upon said receipt of said pamphlets the article was duly catalogued in the card catalogue of the Congressional Library of the United States at Washington, D. C., said card catalogue being made alphabetically under the author's name, the title of the work, the number of pages in it and the number of the copyright. That since that time said pamphlet has formed part of the Congressional Library of the United States at Washington, D. C., and has been open to access to any person who desired to examine it, the said library being a public library.

641 That the copies of the above pamphlet were, as above stated, stamped and catalogued, and that one of the said copies was then placed among the pamphlets on the shelves of said library, its position in the library being indexed in said card catalogue, the said pamphlet being thereafter freely accessible to the public.

That in the summer of 1896, Mr. F. S. Ellmore, having learned of said publication, went to the said Congressional Library and inquired for the said publication in the regular way in which inquiries for books or pamphlets are made, and that in a short time the said pamphlet was produced, and he made a copy of the same.

That the said pamphlet was one of a series of reports made by Mr. Holley, which were sent to the companies manufacturing Bessemer steel in the United States, as well as sent personally to some of the officers and managers of the said companies, said Holley being employed to obtain information in regard to the manufacture of Bessemer steel and appliances therefor, especially as to the European practice, and to furnish such information to the companies in the United States manufacturing such Bessemer steel, and that one of said pamphlets was sent to the firm of which the present Carnegie

Steel Company, Limited, the complainant in this case, is the successor, being practically the same in interest and management, and which firm was then operating the Edgar Thomson steel works, at Bessemer, Allegheny county, Pennsylvania. That said pamphlet was understood as forming part of the literature in the possession of said companies relating to the manufacture of Bessemer steel.

Further, that the said A. L. Holley died in the year 1882, having made his last will and testament, which was duly probated, by which he bequeathed all his library and drawings to the Rensselaer Polytechnic Institute at Troy, New York, as shown by a certified copy of the will of the said A. L. Holley, deceased. That in accordance with the said bequest the library of the said A. L. Holley was,
in the year 1882, delivered to the said Rensselaer Polytechnic
642 Institute at Troy and thereafter formed part of the library of said institute, and among the books and pamphlets so delivered at that time to said institute, were a number of printed copies of the said pamphlet above referred to, entitled "The direct use of blast-furnace metal in the Bessemer process," and marked "Exhibit Holley 1877 Report;" and that the printed copy of said pamphlet which is offered in evidence forming said exhibit, was one of the copies of said pamphlet which were delivered to said institute in the year 1882, in accordance with the said will of the said A. L. Holley. That the library of said Rensselaer Polytechnic Institute was in the year 1882, a public library accessible to all persons at all reasonable times, and has been so ever since that date, and that the said pamphlet has during that time been accessible to the public.

(Signed) BAKEWELL & BAKEWELL,
Counsel for Complainant.

(Signed) JAMES I. KAY,
Counsel for Defendant.

Defendant's counsel offers in evidence certified copy of the last will and testament of Alexander L. Holley, deceased, and the same is marked Exhibit Holley Will.

Defendant's counsel also offers in evidence certified copy of the motion to discontinue the suit of the Carnegie Steel Company, Limited, against the Maryland Steel Company and F. W. Wood, receiver, the affidavit of George Lauder in support of the same and the order of the court made on the said motion, and the same is marked Exhibit Maryland Steel Company Discontinued.

642*a* *Stipulation.*

And now, to wit, March 22, 1897, it is agreed between counsel that defendant's counsel, within 10 days from this date, may recall William J. Taylor, one of defendant's witnesses, and ask him the following questions, complainant's counsel to have the right to cross-examine in person or by written interrogatories:

"Q. When you used the reservoir in connection with the cupola, when melting the old car wheels and scrap as well as the pig metal in the cupola, why was the reservoir necessary?

Q. Did you use the reservoir when melting pig iron exclusively in the cupola, and if so, how far back did you follow this practice?

Q. Was the reservoir necessary when melting pig metal exclusively in the cupola, and if so, why?"

THOMAS W. BAKEWELL,
For Complainant.
JAMES I. KAY, *For Defendant.*

And now, to wit, March 24th, 1897, met at the office of P. T. Dodge, Esq., Tribune building, New York city, pursuant to stipulation filed herewith.

Present: Counsel as before.

William J. Taylor Recalled.

WILLIAM J. TAYLOR, a witness for defendants, recalled in accordance with the stipulation filed herewith, testifies as follows in answer to the questions stated in the stipulation:

"Q. 39. When you used the reservoir in connection with the cupola when melting the old car wheels and scrap as well as the pig metal in the cupola, why was the reservoir necessary?

6426 A. The reservoir was necessary to mix the molten metal from the old car wheels, scrap and pig metal to equalize the irregularities of the metal.

Q. 40. Did you use the reservoir when melting pig iron exclusively in the cupola, and if so, how far back did you follow this practice?

A. Yes, from the time we commenced to make car wheels.

Q. 41. Was the reservoir necessary when melting pig metal exclusively in the cupola, and if so, why?

A. The reservoir was necessary when melting pig metal exclusively in the cupola in order to equalize the irregularities due to all pig iron."

No cross-examination.

Signature waived.

Stipulation.

And now, to wit, March 30th, 1897, in order to complete the examination of the witness JOSEPH MORGAN, JR., by complying with the requests made by complainant's counsel in cross-questions 178 and 179, it is stipulated that if recalled he would testify as follows, and that the same may be considered as evidence in the cause:

In answer to X Q. 178:

The blue print filed herewith and marked "Exhibit Blue Print Open-hearth Furnace No. 1," is a blue print of an old Siemens furnace which has been in the possession of the Cambria Iron Company since 1881, or prior to that date, and is a type of furnace used by the company practically since that time; and the blue print marked "Exhibit Blue Print Open-hearth Furnace No. 2" is a blue print of a furnace used by the Cambria Iron Company with

FOLDOUT(S) IS/ARE TOO LARGE TO BE FILMED

642c the ordinary producer gas, this furnace having been used within late years. These two blue prints illustrate furnaces to be used in the ordinary manner of Siemens regenerator furnaces, gas and air being fed through their respective regenerators forming combustion in the furnace chamber and passing out through flues leading to the opposite regenerators, the current of the gases being reversed at intervals. The blue prints "Exhibit Blue Print Open-hearth Furnace No. 3" and "Exhibit Blue Print Open-hearth Furnace No. 4," respectively, are views of one end of the furnace shown in "Exhibit Blue Print Open-hearth Furnace No. 2," showing the manner in which what was known as "Archer" gas was introduced into the furnace, this Archer gas being a fuel gas formed from oil according to what is known as the "Archer process," and the said gas being introduced through pipes which were arranged to enter either the furnace flues or the furnace chamber as illustrated in the two blue prints respectively, and when this gas was used all of the regenerators of the furnace were used for heating air, the heated air mixing and supporting combustion of the Archer gas, and the furnace being operated in the usual way with the usual reversals of the course of the gases. All of the furnaces illustrated in said blue prints were adapted and intended to be used for the generation of high heat and the melting of iron, the heat being controlled at will of the operator up to this point.

In answer to X Q. 179:

The statement filed herewith and marked "Exhibit Cambria Co. Product Statement" is a true statement of the matters therein set forth from the records of the said Cambria Iron Co., and the facts stated upon said exhibit as to changes made in furnaces or apparatus connected therewith, and other matters affecting the production as found thereon are correct. The extra pig metal shown by said statement as necessary for the running of the Bessemer plant of the Cambria Iron Co. has been made up by purchase of

642d pig metal or by pig metal obtained from other furnaces belonging to the company, but not at Johnstown. Such purchases have now ceased and the furnaces not at Johnstown have been abandoned. Commencing in December, 1892, and extending to November, 1894, the Cambria Iron Co. under agreement with the Johnson Company, also made Bessemer steel which is included in said statement, from pig iron which was furnished by the Johnson Company from other blast furnaces, under an agreement made between the two companies, in connection with which the Cambria Iron Co. took about 137,000 tons of pig metal from the Johnson Company and converted it into steel.

BAKEWELL & BAKEWELL,
Attorneys for Complainant.
JAMES I. KAY,
Attorney for Defendant.

(Here follows photolithograph marked p. 642e.)

643 *Complainant's Proofs in Rebuttal.*

Testimony on part of complainant, taken in pursuance of agreement of counsel, in the city of New York, at the office of the Carnegie Steel Company, Limited, No. 44 Wall street, in said city.

Testimony of Andrew Carnegie.

ANDREW CARNEGIE, being duly sworn, deposes and says, in answer to interrogatories put by complainant's counsel, Mr. W. Bakewell:

Q. 1. State your name, age, residence and occupation.

A. Andrew Carnegie; on the right side of sixty; No. 5 West 51st street, New York; steel manufacturer.

Q. 2. What knowledge have you of the business and costs of manufacture of iron and steel carried on at the Edgar Thomson steel works and other plants of the Carnegie Company, prior and subsequent to the year 1887?

A. The knowledge that the principal of the firm would naturally have of the policy of the company in general since its beginning—certainly most intimate.

Q. 2½. What have you to say as to the need for saving of costs in the remelting of pig iron for converter charges by the use of molten metal direct from the blast furnaces, prior to the year 1887?

A. I have never known the time when there was not need and an intense desire to cheapen cost of manufacture. As a matter of fact, I find that the years 1883, 1884 and 1885 were the worst years we ever knew. Our profits in these years were not half what they were in 1882. In the year 1885 the Edgar Thomson works were shut down in December, 1884, and did not start until May, 1885, for lack of rail orders,—something unknown in their history until that date.

644 Q. 3. State whether or not prior to the year 1887 it was the policy and practice of the company or companies with which you were connected to make use of the best-known means for the manufacture of iron and steel by what is known as the "direct process."

(Objected to as improper in rebuttal and irrelevant to the issues of the case, and also for the reason that the best-known means is shown in the prior art.)

A. Certainly it has always been our aim to adopt the best method both before and after the year 1887.

Q. 4. State whether or not you had prior to 1887 adopted in any of your plants and practically used and tested such direct use of the molten metal commonly known as the direct-converter method.

A. Yes; we began to use direct metal in the year 1882 in the Edgar Thomson works.

Q. 5. What advantages resulted from such use, and state whether or not there were also some disadvantages therefrom. State fully

the advantages, if any, and the disadvantages, if any, resulting from the use of the direct method.

A. There were both advantages and disadvantages. The advantages were that we got less sulphur in the metal by the direct process, and we also thought that we would save cost; but the disadvantages were so great that we often debated whether to abandon the process or not. We found it impossible to get uniform quality of rails, as well as by the cupola method. We found that we could not take metal as the furnaces made it. We tried to fill the furnace cars partly from one furnace, partly from another, but this was not found practicable; trying to tap furnaces at irregular times produced irregular working. I remember being asked by the president of the Cambria Iron Company, Mr. Townsend, to tell him frankly what the result had been, as that company had thought of following our example. I told him of our difficulties.

645 When we were still anxiously struggling with the problem, and undecided whether to continue or abandon it, Capt. Jones, our superintendent, a most ingenious man, told us that he believed he had invented a plan which would solve the problem. He explained to me his idea, which I saw at once to be one based on the system of averages. He explained how he would take the charge of six blast furnaces, placing each into small portions; he could detect in each of these portions the excessive sulphur, for instance, or he could tell whether one furnace was yielding suitable metal or not. He would then have perhaps twenty or thirty car-loads of portions of the output of six different blast furnaces; and he could even select from these small cars at the mixer he proposed to erect, if necessary, such portions as would neutralize each other, thus giving him a system of averages. We thought so well of the idea—I was so convinced of its reasonableness—that I directed him to go ahead with his invention. He did so. My recollection is that the estimated cost was quite a large sum—the books will show this, but I think it was, mixer $48,000 and tracks $15,000. Capt. Jones did so; and almost from that day our troubles ended. He had scored a tremendous success; another step forward was taken in the manufacture of steel; and we are using the invention today.

Q. 6. Had you at that time, when Captain Jones stated to you his invention, a general knowledge of the art of the Bessemer process of the manufacture of steel?

A. I think I can claim to have had this.

Q. 7. State whether or not, at the time referred to, that is when Captain Jones described to you his improvement, you knew of any practical method by which the disadvantages of the direct method of Bessemer steel manufacture, especially the want of uniformity in the product, could be successfully overcome.

(Objected to as immaterial, as the knowledge or lack of knowledge of this witness has nothing to do with the case.)

646 A. Certainly we did not, or we should have had it; but this does not depend upon my knowledge of the art. We had in our service the greatest expert that America ever produced,

Alexander L. Holley, and his duty to us was to report every improvement and every mode of overcoming obstacles; and, if there had been anything in operation in 1881 that did overcome the obstacles, he would certainly have informed us.

Q. 8. You have already stated that, as an economic question, the business of the manufacture of Bessemer steel and its conditions were such as to create a need for such an invention as that of the Jones mixer process. Please to state further whether the conditions of the manufacture as an art did or did not, prior to the year 1887, create a need for such an invention.

A. I have already stated that, without this invention, I believe that we should have abandoned the mode of running direct from the blast furnace. Above all things, the manufacturer has to regard the uniformity of product, the quality of rails, and this uniformity cannot be obtained without the Jones invention, as far as I know.

Q. 9. State what would be the effect in the Bessemer process of using cold pig metal from blast furnaces in the cupolas, without selection or grading and without the use of the Jones invention.

A. I could speculate upon what the result would be, but, as no man ever did it, I think the question cannot be answered. If any works has ever attempted to use metal in cupolas to make steel rails, without grading it and selecting it, we need not seek much further for the so-called mysterious breakage of rails or other failures of rails. There is not a ton of Bessemer pig iron bought or sold which is not upon specifications; and Bessemer metal is graded 1, 2 and 3. If any man in the world has been so reckless as to use pig iron without selection, he should be hung. I noticed my friend,
Mr. Morgan, of the Cambria Iron Company, is sufficiently
647 prudent to say that, when such metal is used, it must be
suitable metal—that is quite right, Mr. Morgan is sound—but he should explain how he determines whether it is suitable or unsuitable, without examination, grading or selecting.

Q. 10. You have spoken in your testimony of Mr. A. L. Holley. Please to state what were your relations to him, both individually and in relation to the companies with which you are connected.

A. I will speak first of him personally, since my regard for him as a friend stands in advance of my regard for him even as our expert. He was one of the most charming men I ever knew. I employed him to build our Edgar Thomson steel works; I consulted with him upon every step of their progress, and every month he rose higher and higher in my regard. Capt. Jones and he were also bosom friends; and I think they were joint patentees of a process of bottom casting. When they did anything in common they went partners. To these two men we owe the Edgar Thomson steel works.

Q. 11. I infer from what you have said that you had large faith in Mr. Holley's knowledge and practical experience as an expert in the iron and steel manufacture?

A. He had no second; he was unrivalled.

Q. 12. State whether or not Mr. Holley's relations with your

company were such as would have necessarily caused him to acquaint you or your company with any important practical improvements in iron and steel manufacture.

A. Certainly; that is what we employed him for.

Q. 13. Do you regard it as possible that Mr. Holley would have kept you and your company in ignorance of any practical method or process with which he was acquainted which would have obviated practical difficulties in the practice of the direct Bessemer process?

(Objected to as incompetent.)

648 A. No; I do not think he would have kept from us any knowledge he had. We do not know positively up to 1877 that he had no knowledge of any plan, because he reported to us in that year; but the problem was unsolved. If any solution had been known up to the time of his death, I am sure Mr. Holley would have known it. The whole trouble was that there was needed, as I have said, some mode by which the law of averages could be brought to bear upon the difficult problem which had troubled not only Mr. Holley, but all of the leading experts in Great Britain.

(Answer objected to as to all matters touching the Holley report as being secondary; and the production of the report in question is asked.)

Q. 14. The defendant's counsel having put in evidence the paper known as the Holley report of 1877, I would ask whether you have read that report, and are acquainted with its contents?

A. I have read it so far as relates to the direct process; and it is to that report which I referred in my last answer.

Q. 15. I now show you a copy of the Holley report of 1877 referred to, and ask you to look at the last part of it, headed "Conclusions;" and I ask you whether, as a practical man, you regard this as describing the invention set forth in the patent in suit, in such manner as to be carried into practice by persons having at that time knowledge in relation to the art?

A. The conclusions on their face bear the answer to that question. First, the necessity of a new mode—something that had n't before been done—is required. Its necessity is recognized; but he says "When the way to its successful adoption is demonstrated," and he also says "But, until this large scale mixer is developed," and so on. The great point is not touched upon here at all. It fails to grasp the soul of the invention—the law of averages; the dealing with successive small portions of metal which can
649 be selected either at the blast furnaces or at the mixer. But Mr. Holley, as you see, recognized the necessity for a further step forward in the art. Mr. Holley lived for five years after his report dated 1877; and if he had found a way to develop the mixer, I think he would have announced it dur- the five years.

(Answer objected to, as giving matters of inference and opinion, and not a statement of facts.)

Q. 16. Do you know what were the relations existing between Mr. Holley and Capt. W. R. Jones, the patentee of the patent in this suit?

A. Most intimate, both personally and professionally.

Q. 17. Capt. W. R. Jones was in the employ of your company for how long a time prior to his death?

A. Capt. Jones was the superintendent of the works from their beginning, and died in our service.

Q. 18. State whether you were well acquainted with him, and how intimately, what were his knowledge and attainments in the arts of iron and steel manufacture, and whether he made any improvements in said arts other than that of the patent in suit?

A. I have been intimate with few men for as many years as with Capt. Jones. In my opinion he was the best practical manager of steel works in the world, at least, I never saw his equal. He made many improvements in our works. I think he did not trouble himself much about taking out patents. The one I have mentioned, bottom casting, he and Mr. Holley took a joint patent for as being really important. The present patent in dispute he also patented, as he believed it his chief contribution to the art of Bessemer steel manufacture. He believed that this gave him place among the great inventors connected with steel.

Q. 19. Can you state whether or not your company purchased the patent in suit from Capt. Jones? If you answer in the affirmative, state, if you know, what price they agreed to pay therefor.

650 A. The company paid all of the expenses of the patent, and owned half of it; and the firm gave Capt. Jones, as I recollect, $35,000 for his half. The captain was very averse to owning anything of a commercial nature. I once offered him an interest in our firm, as it is our policy to interest all our exceptional men. He declined, saying, "I do not know anything about business, and don't want to. I'm a steel man; you pay me a — of a salary." I said, "All right; we will pay you the salary of the President of the United States;" and we did so. In the case of this patent, he wanted $35,000 for a special purpose, and asked the firm to give it to him, and we credited him on the books, paying 6 per cent. interest, subject to his call, and he was notified of this, not four hours before he was killed in our service.

Q. 20. Please to state whether or not there were any European patents obtained for the invention described and claimed in the patent in suit, and whether you are cognizant of the terms upon which those patents were sold, if they were sold, and state what those terms were.

(Objected to as immaterial and as incompetent at this stage of the case.)

A. The right to use the Jones invention was purchased from us for $50,000. The purchasers were steel experts of the highest standing; and the invention is used today, and royalties paid to the holders of the patent.

Q. 21. From your knowledge of the character and attainments of Capt. W. R. Jones, what would you say to a suggestion that he derived a knowledge of the process of the patent in suit and the apparatus therein described, or either of them, from Mr. A. L. Holley or from his reports, or from any other source outside of his own invention, and whether in your judgment of Capt. Jones, either as a man or as an expert in the manufacture of iron and steel, it is probable that he would be apt to copy and patent, as his own invention, the work and suggestion of others?

(Objected to as irrelevant and incompetent.)

651 A. I wish you would ask that question of my friends Forsyth and Hunt or Morgan, Mr. Fritz or anybody who really knew Capt. Jones. If Mr. Holley were alive, and called upon you to answer that question, I think he would do it in a manner that would leave no doubt upon the subject. I never knew a man of whom I could more truthfully say that he was incapable of claiming as his own anything for which he was indebted to another.

Cross-examination by counsel for defendant:

X Q. 22. The complainant company has been the owner for some years of the Duquesne and the Homestead steel works, has it not?

A. Yes, sir.

X Q. 23. When, if at all, was the Jones mixer installed in these works?

A. The Jones mixer has never been installed at Homestead, for we have no blast furnaces there. It has within a month been installed in Duquesne. We had no blast furnaces at Duquesne until recently; therefore it was not practicable to use the direct method until now.

X Q. 24. At Edgar Thomson how many ladles do you have in use at one time, between the blast furnaces and the mixer?

A. I must refer you to our superintendent for that.

X Q. 25. At the Edgar Thomson works, do you know whether or not the ladles of raw metal are delivered into the mixer in the same order in which they are filled from the blast furnace?

A. Upon this and all similar points, I must refer you to the highest authority—the men who are in charge of the daily operations of the works.

X Q. 26. As we cannot compel the attendance of the gentlemen to whom you refer, I am compelled to ask you whether you personally know whether at Edgar Thomson the ladles are emptied into the mixer in the order in which they are filled from the blast furnaces?

652 A. Certainly not. As I understand the operations, certainly not. If everything is running well and the metal is all suitable, I suppose we would do this; but the great point is that the Jones invention gives the superintendents the means of controlling this, whether they will or will not send forward metal which may be at that time unsuitable for combining with the product of the other furnaces. As I have said, it gives them an op-

portunity to avail themselves of the law of averages. But, of course, I cannot give you the details of the works. I am only there a few minutes at a time, and not often each year. The Jones invention is a means of prevention, as well as of cure—it prevents improper mixtures.

X Q. 27. Will you state, for the benefit of the court, in your own language, what you understand the Jones invention to be, as you have referred to it?

A. I have stated my reply to that so fully in the direct question that I just have to repeat it. I refer to Q. 5. I am not a patent expert, but give you the broad general idea of the invention and testify to its results.

X Q. 28. May it not be the practice at Edgar Thomson to take the ladles of unsuitable metal from the blast furnace and run the metal into the pig bed, instead of holding it in a molten condition for future delivery into the mixer?

A. This could be done if the superintendent knew that the metal was working so very poorly that the metal would be so bad that the law of averages would not apply to it. In that case the superintendent might decide to throw off that furnace entirely; but, in practical operations, the metal, though unsuitable in itself, may not be so far beyond the range as to render it impossible to bring it to an average standard by mixing it with the other successive portions. It must always be remembered in making steel that, if there be one chance in a week of a bad batch of rails, as was the case
653 before the Jones invention, it is impossible for a conscientious manufacturer to go forward. He must incur more trouble and expense to guard against this contingency than the direct process is worth. The great merit of the Jones invention is that it was a commercial success, as well as a successful invention. That is the reason that most works wished to adopt it.

X Q. 29. I intended asking not the possibilities, but the actual practice at Edgar Thomson, as to the disposition of the ladles of unsuitable metal from the blast furnaces. Can you say, of your own knowledge, that they do at Edgar Thomson hold back ladles of molten metal to be subsequently delivered into the mixer when the quality of the metal from the furnace changes?

A. I know that that was one of the advantages that Captain Jones claimed for his invention, that this could be done whenever necessary. Of course I do not know by my personal knowledge whether it is the practice or not.

X Q. 30. Before the introduction of the Jones mixer, how was the direct metal handled between the blast furnaces and converter?

A. It was run direct; I could not tell you the details. Of course, what I have heard is, that it was taken in all kinds of ways, sometimes they thought they could run a charge up direct—sometimes they thought it was necessary, I think, to have another furnace tapped, but I do not know whether they ever put more in a ladle than what came from one furnace. They may have done so, but the general result was that we could not work satisfactorily running direct from the blast furnace.

X Q. 31. Do you know whether they ever practiced at Edgar Thomson the mixing of metal from the blast furnace by simply pouring into a charging ladle a number of small portions of molten metal, taken from several ladles or vessels?

A. I do not know; but I do know that during the time we were struggling with the problem of running direct, I think Capt.
654 Jones tried almost everything. I am sure from his anxiety to succeed that he would do so. Perhaps he did that. I do not know. But if — had found that practicable, it would have been unnecessary for him to invent a mixer.

X Q. 32. Will you explain for the court what you mean by the "law of averages"?

A. Yes, sir, that I can do. Thank you for asking me that question. If you take a thousand men from the street, you will find some short, some tall, some fat, some lean. But, when you average the thousand, you will find substantially the same standard which you will find if you take every thousand men in the United States. This is the law of average. Now, apply this to the Jones invention; some metal is too high in silicon, some too low; some too high in sulphur, some too low; some too high in phosphorus, some too low. Taking each portion by itself, you must get steel totally unfit for use, not safe to use, for one condition of good steel is that its elements combined must produce a certain standard, both as to its elements and to its quality. Now this is what the Jones invention does for the direct process. You are no longer compelled to take one portion or two portions of unsuitable metal. To get one man short and another one tall, or one batch of steel too high or too low in any of its elements, but by covering a broad field, having successive portions of metal which you can take at the proper moment and combine with other portions which are perhaps lacking in an element in which the delayed portion has excess, you bring the direct method of manufacturing steel under the law of averages, wherein alone rests safety.

X Q. 33. In the mixing of metals, to obtain the general average, the greater number of elements or portions mixed, the better the average, as a rule?

A. Certainly; and some of our furnaces give much larger
655 product than others. For instance, our Duquesne furnaces, giving us 100 tons at a charge, we of course could use more vessels making a wider average.

X Q. 34. As between mixing two portions and two hundred portions, for example, the difference is one in degree and not one in principle, is it not?

A. Up to a certain point, that is so. But it is not so beyond a certain point. It does not proceed in a geometrical progression. As I understand the law of averages, thus, if you take two men, you might get a long man and a short one—thus, if you took two portions of steel, both might be wholly unsuited to use even in the mixer, but if you took a dozen men, probably you would come much nearer an average. In short, there is no average and can be none without a large number of successive portions, but the practice will

determine about what that number may be. It depends upon the furnaces; and the ores used, and the management of the furnaces, and upon the lime and fuel. The number of successive portions is determined by practice, but two portions, or three, would give no average.

X Q. 35. In using the direct metal previous to the installation of the Jones mixer, one of your serious difficulties was due to the fact that, in filling successive charging ladles from the blast furnace, the different portions at one tap would differ as to the silicon contents, was it not?

A. I believe that was one.

X Q. 36. At the Edgar Thomson works, previous to the Jones mixer, did you ever try mixing or running together the entire tap of a blast furnace, and taking from this body the charges for the converter?

A. I really cannot say. I don't think we ever had a vessel that was big enough to take one tap. As I said before, I should hesitate to put a limit to what was tried, as I believe Capt. Jones tried everything under the sun.

X Q. 37. Would it be fair to describe the Jones method as the mixing of molten metal from two, three or more blast furnaces to get a better average metal?

656 A. No, it would not. I have just said that two furnaces wouldn't make an average. We run six blast furnaces, and it is essential that successive portions from many blast furnaces should be dealt with, as I have explained, so that an average of the elements can be obtained. That is one point upon which I think your description not full. There may be others. I am not a patent attorney, and I do not know what is necessary to describe a patent in your possession.

(The witness not professing to be a patent expert, and not having been examined as such, it is not considered proper to put to him purely expert questions; and this line of examination, for this reason, is objected to by complainant's counsel.)

X Q. 38. What is the smallest number of blast furnaces which you believe allowable to carry out the Jones invention as you have described it?

(Objection continued.)

A. That depends upon conditions. If a works is melting the purest of ores, has the best fuel, lime, and the furnaces as a rule work with great regularity, then at that works the average necessary for safety and for making good steel, practically, would be smaller than at a works which had to deal with poorer ores, more irregular, worse coke and lime, more irregular. It might take ten furnaces at the latter works to give as good results as five would do. No man can say how many or how few—this is a matter to be determined by experience.

X Q. 39. In what year were the Edgar Thomson works built by Mr. Holley?

A. From '72 to '76. They were stopped by a panic.

X Q. 40. When Capt. Jones described his invention to you, as you have stated, were there any drawings of any apparatus made by him?

657 A. He did show me drawings, but whether at the time he described it or not, I am not sure. Afterwards, I did see drawings at the works.

X Q. 41. Mr. Holley, as an expert, made reports and recommendations to your company, as he did to the other steel companies, did he not?

A. Mr. Holley planned and built our works. He was not in joint employ then with others and ourselves. He was specially our man. I think that it was probably in '76 that he became the agent of the Bessemer Association, of which we were a member. In that way, all the works received his report.

Adjourned to meet at same place tomorrow morning, January 29th, 1897.

JANUARY 29TH, 1897.

Met at same place pursuant to adjournment.

Present: Counsel as before.

Cross-examination continued:

X Q. 42. Do you know whether the Holley report of 1877 was sent to and received by the Edgar Thomson Company or Mr. Jones at or about the time it was issued?

A. I do not.

X Q. 43. When did you first know of the Holley report?

A. I really cannot tell you when I heard of the Holley report, that special report. I hadn't thought of the thing for thirteen or fourteen years until it came up again the other day, when it was perfectly fresh. I am vice-president of the British Institute, and have met the numerous experts, Snelus, Richards, Evans and others, and the subject of Jones' invention has come up now and then, and the captain duly praised for the important invention he had made, which had solved the problem they had been discussing a long time ago. I cannot approximate it. I cannot say that I ever read the report or saw it. I kept advised in general of the state of the art.

658 X Q. 44. It is a fact, is it not, that the English companies who operate under the Jones patent, do so on the basis of six cents per ton royalty?

(Objected to as not proper cross-examination.)

A. I have never heard what the royalty was, nor whether they paid a royalty or purchased outright.

X Q. 45. Do you know whether or not English makers of steel have refused to pay royalty for the Jones patent?

(Objection continued.)

A. I have never heard anything of the kind.

X Q. 46. I am advised that there are English makers who refuse to recognize the Jones patent or pay for the use of the Jones invention. Are you in position to deny that this is so?

(Objection continued.)

A. I have never heard that this is so, but shall not be surprised if it be so. There are very few inventions which some one or other is not willing to use and not pay for.

X Q. 47. What proportion of the English steel plants have applied for or received the right to use the Jones invention?

(Objection continued.)

The attention of the court is called by defendant's counsel to Q. 20 and the answer thereto.

A. I cannot tell. You would have to apply to the owner of the foreign patents for that information. We have sold it to them and no application would be made to us. We have nothing to do with the arrangements made by the owners abroad.

X Q. 48. Have you personally no interest in the Jones British patents or in the company controlling them?

A. Not the slightest. I never have a personal interest in anything connected with iron and steel. Such are always held by the firm.

X Q. 49. Do you know who composed the syndicate owning the Jones British patents?

659 A. I do not. I only know the party who bought the patents from us. That was a Mr. Evans. I know of no one else.

X Q. 50. In what respect does the Holley report of 1877 fail to describe the invention which Mr. Jones described to you and made the subject?

A. It is the difference between a want recognized and the means to meet that want. Mr. Holley was the man who knew that the egg had to be set on end, and Capt. Jones was the man who set the egg on end. That is the difference. If Mr. Holley described Mr. Jones' invention, then he would have developed the necessary appliances; then there would have remained no problem to solve. That is the broad fact in the case.

X Q. 51. That the court may understand, please name or state specifically what "means" Capt. Jones disclosed to you which are not disclosed in any part of the Holley report.

A. I refer you to my answer — Q. 15, where I say the great point is not touched upon in Mr. Holley's report at all. It fails to grasp the soul of the invention,—the law of averages,—the dealing with successive small portions of metal, which can be selected either at the blast furnaces or at the mixer. But Mr. Holley, as you see, recognized the necessity for a further step forward in the art. Mr. Holley lived for five years after his report dated 1877, and if he had found a way to develop the mixer, I think he would have announced it during the five years. Such is my answer to Q. 15; and I do not see that I can do better than repeat it.

X Q. 52. The wheeled ladle shown in the Holley report of 1877 is essentially the same in construction as the ladle shown in the Jones patent for receiving the blast-furnace metal and delivering it to the mixer?

A. Excuse me, gentlemen; I must again say that I am no mechanic nor patent expert, and I must frankly say that I can-
660 not answer as to the details of mechanical appliances. All I know is the broad, general fact. We were in trouble in regard to the direct process, and Capt. Jones' invention entirely relieved us.

X Q. 53. Can you tell me from recollection or otherwise how many ladles were used between the mixer and the blast furnaces, or how many blast furnaces were used during the year following the installation of the Jones mixer?

A. I cannot. That is another detail which I cannot meet. The present practice I know is to use six blast furnaces; further than this I cannot go.

X Q. 54. For how long a period did the Edgar Thomson works use blast-furnace metal direct previous to the Jones mixer?

A. We introduced the direct some time in 1882. My recollection is—but I may be altogether wrong—that we began its use tentatively. We used cupolas for part, and only part direct. I know that Capt. Jones suggested that to me as practicable, so that there was little danger in introducing direct. I think, but, of course, I may be all wrong again, that we continued to use cupolas in emergencies whenever the metal from the furnaces became so irregular that we could not trust taking all direct metal. We kept all our cupolas ready, did not destroy or remove them, with this end in view. The exact date at which we abandoned this reserve I cannot tell; but we were always on the ragged edge, as it were, in regard to the use of the direct metal until Capt. Jones' invention was introduced. I cannot give you details; but we will put a manager on the stand who can do so. We wish to give you everything pertaining to the whole matter.

X Q. 55. Referring again to the Holley report of 1877, I call your attention to the description of the "Unfinished works" on page 16 of that report, and ask you to state wherein that description fails to describe the Jones invention as you understand it.

(When the counsel for the defendant wish to use Mr. Car-
negie as their expert, they will please give us notice, so
661 that we may know how the matter stands, but counsel for complainant objects to defendant's counsel examining Mr. Carnegie on expert questions.

Defendant's counsel calls the court's attention to Q. 14 and Q. 15, in the latter one of which the attention of the present witness is called to a certain part of this Holley report, and he is then asked as follows: "I ask you whether as a practical man, you regard this as describing the invention set forth in the patent in suit, in such manner as to be carried into practice by persons having at that time knowledge in relation to the art.")

A. And referring you again to my answer to Q. 15, which I have given twice, I must most respectfully decline to figure here as an expert of any kind whatever.

X Q. 56. You expressed your opinion as to the part of this Holley report in your answer 15. I now refer you to the part of it entitled "Unfinished works," on page- 16 and 17 thereof, and ask if you have read it, and, if you have not read it, I would request that you will do so, and answer my last question?

A. My answer is this: I referred to the conclusions in Mr. Holley's report, and gave you my answer twice. I see that this is a long description of mechanical devices, taking up nearly two pages. I have not read it, and, if I did so, I believe myself totally incompetent to give an opinion as to whether these appliances describe any invention. I am no mechanic, and reiterate that all I know is the broad general result. You must go to experts for opinions upon details.

X Q. 57. In answer 5 you have described what you understand to be the Jones invention. Would this invention, as you understand it, include tapping of the molten metal from two or more blast furnaces into a vessel or receiver to get a better average which will be more suitable for making Bessemer steel or metal of uniform
662 quality and drawing from the vessel weighed charges of the molten metal as they are needed for the converter?

A. No, I do not think it would, unless you had a mixer. It is the combination of various things, as I have explained, that gives an average. There is one point, however, that occurs to me that would infringe the Jones patent, thus, if you tap—I am no expert, and don't pretend to give an opinion, but will tell you what occurs to me. If you have more than one vessel, because if you draw from a blast furnace into several vessels, the first portion is of different character from the second portion, and the third portion differs from both, but, if you draw into one vessel the whole charge of the furnace, and the vessel be half full, and you go to another furnace and draw another half, I do not think that that would be covered by the Jones patent as I understand it; because this would involve tapping the furnaces at irregular times. I have heard that it has been tried, and found impracticable. The essence of the Jones patent, as I understand it, is that the appliances invented by him enable successive portions of metal to be combined according to their respective constituents, and this over a number of portions large enough to secure the uniform standard necessary.

X Q. 58. I had intended my question to include the use of a mixer, and I will restate it. Would the Jones invention, as you understand it, be present if you drew in any way the tap or cast from two or more blast furnaces into a mixing vessel or receiver to get a better average for making Bessemer steel, and you drew from this mixing vessel weighed charges of the molten metal as they were needed for the converter, and again filled up the mixing vessel with fresh molten metal?

(Objected to as asking for an opinion on a hypothetical case and for expert testimony when the witness was not offered as an expert.)

A. I really have difficulty in following this. You did not
663 ask me the question you intended to ask, and your question is now so long and involved that I hesitate to answer it. As I have told you, I am not an expert; but the only point I see in your question is whether drawing from two furnaces—I really do not understand your question.

X Q. 59. Would the Jones invention, as you understand it, include the carrying of the taps or casts from two or more blast furnaces into a mixing vessel or receiver to get a better average for making Bessemer steel, and the drawing from this mixing vessel weighed charges of the molten metal as they were needed for the converter, and the filling up again of the mixing vessel with fresh molten metal?

(Objection continued, with the additional one that the interpretation of the patent and of its scope is the province of the court, and that the question is therefore evidently an improper one.)

A. You have repeated your question; and I repeat my answer. As I understand it, the object of this action is to have the courts decide what or what not is included in the Jones invention as to details. I cannot deal with hypothetical questions embracing mechanical details. I am wholly incompetent.

X Q. 60. When did you erect the blast furnaces at your Duquesne works?

(Objected to as not proper cross-examination.)

A. We began, I think, about eighteen months ago. Two of them are finished and running, and the others are approaching completion. We expect to have them all finished about the beginning of April. One has been running, I should say, six or eight months, the other two or three months.

X Q. 61. About how long has your company or its predecessors owned the Duquesne and Homestead works?

(Objection continued.)

664 A. We have owned the Duquesne, I should say, about five years, and Homestead more than ten years.

X Q. 62. Can you give me or have ascertained so that it can form part of the records, the tonnage of Bessemer steel made at the Duquesne and Homestead works since 1887?

A. It amounts to many hundred thousands of tons. You can ask the exact amount of any of our managers who appear.

This with the understanding that the information will be furnished from witnesses produced to whom the question can be put.

X Q. 63. Do you know the percentage of seconds produced at the Edgar Thomson works during the years 1882 to 1890?

(Objection continued.)

A. No, sir.

X Q. 64. You refer, in your answer 21, to your friends Forsyth and Hunt and Morgan and Fritz. Please identify these men, and

state how prominent their connection has been with the manufacture of Bessemer steel in this country.

(Complainant's counsel objects to the latter part of the question.)

A. Hunt and Forsyth and Morgan were examined as witnesses for the defendant, I believe.

Mr. Fritz was the superintendent of the Bethlehem works. He made his record as an inventor of rolling-mill machinery. Mr. Hunt was formerly with Cambria—I don't know in exactly what position. I do not know anything that Mr. Hunt has invented bearing upon the art. Mr. Forsyth was superintendent of the Illinois Steel Company; have always heard him spoken of as an excellent manager, but I do not think he ever invented anything bearing upon the art. Mr. Morgan was superintendent of the Cambria Company; and the same thing may be said of him, that he never invented anything bearing upon the art.

665 X Q. 65. Is it not a fact that Messrs. Hunt and Forsyth have been very prominent among the makers of Bessemer steel in this country?

(Question objected to for the reason that the gentlemen mentioned in the question were witnesses for the defendant, and it is for them to prove the standing of their own witnesses, and they have no right to call upon us to do so.)

A. Yes; prominent as makers, because they were each superintendents of the few large Bessemer works then in the United States; but, as I have said, not as inventors or men who have improved the methods. They were good superintendents.

Redirect examination by Mr. BAKEWELL:

R. D. Q. 67. In your answer to Q. 20, you stated that "the right to use the Jones invention," referring to the European patents, "was purchased from us for $50,000." State whether you referred to a license to use the invention only or to the sale of the patents.

A. My understanding was that it was a sale of the patents.

R. D. Q. 68. You are asked in X Q. 37 whether it would be fair to describe the Jones method as the mixing of molten metal from two, three, or more blast furnaces to get a better average metal. To avoid padding the record, I hand you your answer to that question, and ask if you will please further explain in regard to the matter, if you have anything further to say?

A. This question, as put, strikes me as omitting a very important point. If the question means here that you can draw from two or more furnaces, that it is not limited to two, as I understood the question, and if it means that from two furnaces successive portions of metal were to be taken, then it might be possible to get a sufficient number of successive portions, perhaps, from two furnaces to reach the average standard. In that case the aim of the
666 Jones invention would be accomplished, an average might be obtained. In this way it is possible that two furnaces would

make an average. I thought the question was limited to two, so that two furnaces operated as I have described might or might not obtain the average mixtures. At all events, it would double the chances of obtaining the average mixture. We have only two furnaces at Duquesne just now running for the mixer, and this, of course, improves the molten metal, but it is evident that if we had two more running in, as we shall have, the number of successive portions running for the mixer being increased, we should have greater certainty of obtaining more uniform metal.

R. D. Q. 69. If you run the metal from a single blast furnace, and tap your metal into three ladles and run direct to the converter, what would be the result as to uniformity, this being, as I understand it, the ordinary way of running blast furnaces?

A. I think that I have said that I have been informed that the first ladleful from a blast furnace differs from the second, and the second differs from the third. Therefore, if, instead of taking the first portion direct to the converter, we took the three to the mixer, that would be a mixture of the three, and the peculiarities of each portion would thereby be brought nearer an average. But, if you take from two furnaces two first charges and two second charges and two third charges, it is probable that putting in the two first charges would not make so much difference, because, as I understand, the two first charges would have a common character.

R. D. Q. 70. If you run the molten metal from a single furnace, and pour in the successive portions into a mixer containing a comparatively large amount of metal, what would be the result as to uniformity in the portions drawn from the mixer, and state whether, in your opinion, this method would or would not be covered by the Jones invention as you understand it.

667 A. Is it assumed that the large portion of metal in a mixer is of successive portions drawn from several vessels? If the large portion of metal in the mixer was of the standard quality, then the introduction of successive portions of metal would give metal of the standard average quality, and would therefore, in my opinion, be embraced in Jones' invention.

R. D. Q. 71. When you say in your last answer that the successive portions of metal would give the standard average quality, state whether or not you mean successive portions of metal drawn from one furnace.

A. Yes; successive portions from the same furnace, but let me be clear upon this point. All depends upon the average quality of the metal that was in the mixer and the amount of metal. It is easily conceivable that the metal in the mixer might be irregular or that the metal from the blast furnace put in might be irregular. It all depends upon whether a mixture takes place of such suitable metal as in combination will produce the standard quality.

Recross-examination:

R. X Q. 72. Stripping the matter of technicality, is it not a fact that the whole effort is to mix differing portions of molten metal in

any way or size or number, that will give the required general average?

A. Yes; that is the essence of the invention. To do this practically, economically and in such manner as will solve the problem to the solution of which Mr. Holley and other experts have so anxiously looked forward, so that it is practicable to take the metal from blast furnaces, mix it in successive portions in such manner as to render the molten metal suitable and safe to be manufactured into good steel. No plan of mixing or no device that I have ever heard of ever did that successively, as is proved by the fact that no plan, many as have been tried, was ever continued in use. Capt. Jones came along, and, as I have said, set the egg on end.

(After the first sentence objected to as irresponsive and voluntary.)

ANDREW CARNEGIE.

668 *Testimony of Julian Kennedy.*

PITTSBURGH, *March* 29, 1897.

JULIAN KENNEDY, a witness called and sworn on behalf of complainant in rebuttal, deposes and says as follows:

Q. 1. State your name, age, residence and occupation.

A. Julian Kennedy; age, 45; residence, Pittsburgh, Pa.; occupation, mechanical engineer.

Q. 2. What practical experience have you had in the manufacture of iron and steel, and what study have you given to these and to analogous matters which would qualify you to speak as an expert on subjects relating to the manufacture of steel?

A. Since the age of 18 I have been constantly engaged in works which manufactured iron and steel, with the exception of four years when I was in college and one year that I was superintendent of a bridge works. After spending three years with the Struthers Iron Company, Struthers, Ohio, as draughtsman during construction and as one of the engineers standing turns in charge of blowing engines, pumps, etc., I entered the scientific school of Yale college in 1873, graduating in 1875, and remained there during 1876 as instructor and lecturer in physics, with charge of the physical laboratory. After this I superintended works for the Brier Hill Iron Company, Youngstown, Ohio, for one year, and for the Morse Bridge Company of the same place for one year, after which I was manager of the blast-furnace department of the Edgar Thomson steel works, at Braddock, Pa., for about five years. I was then manager of the Lucy furnaces of Carnegie, Phipps & Co., of this city, for about three years, at the same time acting as consulting engineer for the furnace department at Braddock. After this I was general superintendent of the works of Carnegie, Phipps & Co. for a little over two years, having charge of the Homestead steel works, Lucy furnaces and Twenty-ninth Street
669 mills of the above named firms. After this I was two years with the Latrobe steel works as chief engineer in charge of

construction, a position which I still retain. In addition to this for the last six years I have been doing a general business as consulting and mechanical engineer, making a specialty of the designing of blast furnaces, Bessemer and open-hearth works and rolling mills. From the time I commenced work at the Edgar Thomson works I had full charge of construction on the grounds, and after being there two years I had entire charge of all designing as well as construction, and in all the other works with which I have been connected since, I have also had full and entire charge of designing and construction. Since the time I went to the Edgar Thomson works I have been in the habit of visiting iron and steel works very frequently, and have visited a large number of the most prominent iron and steel works of the country, many of them repeatedly, and have tried to observe everything in them carefully. I have designed a considerable number of mills for rolling iron and steel. I am acquainted with a large number of the engineers and superintendents of the most prominent mills in the country, and am accustomed to compare notes with them in regard to the construction and operation of mills, and in a general way have endeavored to keep well informed on current practice in iron and steel works.

Q. 3. Please examine the Jones patent in suit, 404,414 and considering the description and the second claim in connection with the drawings, not as a patent specification, but as an illustrated description of a method of mixing molten pig metal, state what you understand to be the method therein disclosed and its advantages, if any, in the manufacture of Bessemer steel.

A. As I understand it, the method which is described in the specification consists essentially in taking small portions of metal
which have been tapped from one blast furnace or from sev-
670 eral blast furnaces, as the case may be, and in pouring these
small portions successively into a large receptacle or mixing vessel which is kept constantly full or nearly full of molten metal, and in like manner drawing off from the mixer from time to time the comparatively small portions of metal which constitute the charges of the Bessemer converter. The effect of thus drawing off small portions of metal from the large receiver and then filling it up again by the addition of other small portions, the amount remaining in the receiver being always very considerable in proportion to the amounts drawn off and charged at any one time, is to prevent abrupt fluctuations in the chemical and physical characteristics of the successive portions drawn off from the mixer, even when the corresponding characteristics of the successive portions which are charged in to the mixer vary suddenly and widely.

To illustrate: If you take a mixing vessel containing 90 tons of molten iron, whose content of silicon is, for example, 2 per cent. and add to this a charge of 10 tons of molten iron containing 4 per cent. of silicon; we should then have a mixture containing 2.2 per cent. of silicon. If we now draw off 10 tons from the mixer, and then add 10 tons more containing 4 per cent. of silicon, we should have a mixture containing 2.38 per cent. of silicon. By again drawing off 10 tons and replenishing with 10 tons more of iron contain-

ing 4 per cent. of silicon, we should have a mixture in the vessel containing 2.54 per cent. of silicon. So that it is perfectly plain that with a mixer operated by this method, it is possible to have very wide variations in the composition of the blast-furnace metal at successive tappings, and at the same time to have the successive charges for the Bessemer converter show quite small and gradual changes of composition. This will continue constantly from day to day, the metal varying slowly and gradually, so that the composition of one charge can be quite closely determined from an analysis of the preceding charge and its working, thus enabling the man operating the converters to regulate their operations with
671 very great nicety, with the result that much smoother working and a better quality of product can be obtained.

These results are not obtained by the practice of taking metal from two blast furnaces by running a train of ladles in front of them and tapping into each ladle half a charge and filling it from a second furnace. By such practice, of course, there is some independent equalization of the composition of each ladle or of the ladles of each group, but it affords no further advantage, and in fact, would not obviate the difficulties of direct-metal working. It does not enable the converter manager to for-tell the character of each charge from the character of the preceding charge, and would, therefore, entail the uncertainties of operation and the irregularity of product which the Jones method avoids. Thus, in the ladle practice above mentioned, it might happen that two furnaces would produce iron too high in silicon at one cast, and too low at the next cast. The effect of this would be that the converters might receive five or six charges all alike and all high in silicon or sulphur, and then receive six more charges, also all alike, but differing from the preceding six quite widely in the amounts of silicon and sulphur, and the manager of the converters could form very little idea from the first group of charges what the composition of the second group would be; whereas, if these charges had been put through the mixer as described, the six charges which were too high in silicon would have gradually raised the percentage of silicon in the mixer, and the succeeding six charges while being transferred through it would have gradually reduced it again, the changes being slow and gradual and the maximum variation from the percentage of silicon in the mixer in the beginning of the operation, being less than half the difference between this percentage and the percentage contained in the six charges of high silicon iron or those of low silicon iron. That is to say, given a mixer of iron containing 2 per cent. silicon and put into this six charges of iron containing 3 per cent.
672 silicon, and then six more charges containing 1 per cent. of silicon, during this time we should not have present to exceed $2\frac{1}{2}$ per cent. nor less than $1\frac{3}{4}$ per cent. of silicon.

Not only does this method cause the chemical composition of the metal to change slowly and gradually, but the same effect is produced on the temperature of the metal, and any wide variation of temperature is equalized and controlled in the same way as the chemical composition. This is important from the fact that the

heat generated in the converter is dependent on the initial or sensible temperature of the charge as well as on the amount of silicon present, the silicon being the principal fuel or heat-giving element in the Bessemer process and more silicon being required for successful operation when the initial temperature of the iron charged into the converter is low.

Ever since the invention of the Bessemer process, it has been well recognized that great economies could be attained by transferring the molten metal from the blast furnace to the converter without allowing it to solidify. Until within a few years, however, this direct process, as it has been called, has not been generally used. It is easy to see why this was the case. The fluctuation in the chemical composition of the metal from the blast furnace was too great to allow that degree of uniformity of product in the Bessemer steel produced from it which is absolutely necessary in the case of steel rails, for example, which must be as reliable as human skill can make them and where no reasonable expense can be spared to make them perfectly safe and trustworthy. A very few broken rails in a track, with the damage to property and human life which this might cause, would far more than offset any possible saving in a year's work, due to the use of the direct process. For this reason the practice, until within comparatively recent years, has been to cast the metal in pigs, then to analyze it and reject any portion not closely approximating a rigid specification in its chemical
673 composition, and to select, mix and then melt the approved metal in cupola furnaces. By this means very great uniformity of chemical composition of the remelted metal can be obtained, and good and reliable steel made from it with regularity and certainty.

The object of the Jones method is to obtain this same result and at the same time eliminate the very considerable expense involved in casting the metal into pigs and remelting it in the cupola. It would, of course, effect no saving if applied to metal after being remelted in the cupola. The ordinary method of remelting in the cupola leaves practically nothing to be desired in the way of uniformity of the fluid metal so produced.

The Jones method, as will be seen from the specification and second claim of the patent, is intended solely for use with crude molten metal taken from the blast furnace, which is the only kind of molten metal mentioned in the patent.

The Jones method has been eminently successful in practice and has done away with the objections to the use of the direct process. These objections, recognized at the date of Bessemer's invention, had never been overcome, although constant efforts had been made in that direction by many of the ablest metallurgists.

Q. 4. You have spoken of the facility which the Jones method affords of judging from the character of each blow at the converter what the character of the next will be. Please explain the importance of this and how the Jones method enables it to be done. If, in order to make this matter clear, you think it necessary to describe generally the Bessemer process of steel-making, you may do so.

A. In making Bessemer steel the liquid iron is poured into the converter and is subjected to the blast of compressed air, which entering from below in numerous streams attacks and burns out the silicon and carbon, the end of the operation being determined by the appearance of the flame which issues from the mouth of the converter.

674 The time of this operation varies with the amount of the material to be removed from the iron, running from six or seven minutes up to 15 minutes, or even more.

The Bessemer process, unlike the open-hearth process, requires that the operation be terminated at exactly the right moment. If the vessel be turned down and the blast shut off too soon there will be some carbon left in the iron, and if it be turned down too late, the iron will be overblown or partly oxidized. To stop the operation at exactly the right time requires not only long experience and great skill on the part of the blower, but also a sufficiently uniform iron. For example, the blower who has been working on low silicon iron and is suddenly provided with high silicon iron, will generally have to blow several heats before he succeeds in stopping the operation at exactly the right time. Wide variations in the composition of separate heats are therefore both troublesome and expensive, and if widely different irons follow each other the blower is very apt to make irregular and unreliable steel. Not only is it difficult in such cases for him to tell the exact time when the operation should be stopped, but it is difficult to control the temperature of the metal in the converter, so that the steel produced is apt either to be too cold or too hot for successful casting. Hence defective ingots, flaws and brittleness in the finished product.

In the open-hearth process, when the steel is supposed to be finished it is quite feasible to take out a sample and test or analyze it, and if the composition is not right it can be changed by adding additional material to the molten steel in the furnace. The Bessemer process on the other hand, instead of taking from six to eight hours to make a heat, takes as many minutes, and a variation of a few seconds from the time of stopping the process may mean the difference between good and bad steel, so that it is very important that the iron delivered to the converter should be as uniform as possible; and it is also important that all changes in the compo-

675 sition and initial temperature of the iron should be as slow and gradual as possible, so that the blower may not be called upon to blow successive heats of widely varying behavior in the vessel. Such slow and gradual change also allows the foreman to judge very accurately how much scrap should be added to control and keep uniform the temperature in the converter.

Q. 5. Please examine British patent 3672 of 1873 to William Deighton, and state whether, in your opinion, — discloses the Jones method of mixing molten pig metal.

A. The Deighton method contemplates the use of a receiver into which two or more furnaces can be tapped, the idea being to get a better average metal by mixing the metal from two or more furnaces. This method is more like the method of partly filling ladles

at one furnace and then taking them to another, than to the Jones method. In the Deighton method a whole cast from a furnace would be run into a receiver at once, whereas in the Jones method the cast from one furnace is subdivided into a number of comparatively small portions, which are then charged one at a time into the mixer, alternating them when necessary with correspondingly small portions from other furnaces.

A wide difference between the Deighton and Jones method is that in the former the entire cast of a blast furnace, or of two or more blast furnaces, is poured at once into the receiver, with the radical changes in the chemical composition and sensible heat that would naturally result, while the material is withdrawn therefrom in the comparatively small quantities necessary for charging the converters, so that the balance between the additions to and the withdrawals from the receiver is not preserved, an efficient equalizing pool is not maintained, the changes in the character and temperature of the metal are abrupt and not gradual, and the advantage of a slow and gradual change as a guide in the treatment of the metal is not obtained.

676 The Deighton specification is very meager in details of description, but my opinion is that it was his idea to tap all of his blast furnaces simultaneously. If so, the addition of such a very large quantity of metal to the receiver would be attended with more or less frequent wide and abrupt changes in the constituents and temperature of the metal in the receiver. The metal therein, if working with the number of converters usual with such a number of blast furnaces, would be nearly, if not entirely, exhausted between the casts of the furnaces, and a slow and gradual variation between successive casts would be impossible. There is no suggestion in the Deighton patent of an equalizing pool of metal, or of the necessity or desirability of one, and nothing, in my opinion, that would suggest such an idea.

Deighton's method made no impression on the art. It is not known to have ever been put into use, and it certainly did not lead to the solution of the difficulty attending the use of direct metal. In this connection it is significant to remark that Deighton was a designer, draughtsman and roll-turner of Workington, England, the home of the Moss Bay Company, of whom Mr. Snelus, in the discussion of Holland's paper in 1878, four years later, said:

"The Moss Bay Company attempted to modify the thing (the intermediate ladle used in America) some time ago and put up a heating furnace, but that to his mind was a step in the wrong direction. Anyhow, the thing had failed, and no one in England, as far as he knew, was using any intermediate receiver between the blast furnaces and the converters."

Another practical difficulty of the Deighton method would be that a certain cast from one of the blast furnaces might be of a very bad quality, in fact, too bad to put into the mixer at all, and this in some cases cannot be known until after the furnace has been tapped. In the Jones method, on the other hand, the cast not being

run directly into the receiver, an opportunity is afforded to
677 test the metal, and, if it is too poor, to keep it out of the mixer altogether. It is not at all unusual in the operation of a large blast furnace to get a cast which is not desirable to put into the mixer, and which is cast into pigs and put through the furnace again. It is quite possible to keep the several portions of the cast fluid until all necessary tests are made, after which it can be charged into the mixer or otherwise disposed of as may seem desirable.

For these reasons I do not think the Deighton method would accomplish the good results obtained by the Jones method, nor do I think it could ever be operated so as to become a commercial success. The Deighton method would give wide variations, both in the chemical composition and the temperature of the metal.

Q. 6. Please examine the following patents granted to Z. S. Durfee: British patent No. 685 of 1872; U. S. patent 11598, dated August 29, 1871; U. S. patent 122,312, dated January 2, 1872, and the letter of Z. S. Durfee, dated September 23, 1874, and published in Engineering, vol. 18, p. 310, copies of which have been offered in evidence by the defendant as exhibits; and state whether, in your opinion, the Jones method is disclosed in any one or more of these exhibits?

A. The method disclosed in the Durfee exhibits consists in transferring metal from the blast furnace into an open-hearth furnace for the express purpose of treating it so as to change its characteristics. It is stated that pig other than that taken from the furnace may be melted down into the charge. It is also stated that iron which is too low in silicon and carbon for successful use in the converter can be made to work well by considerably raising its temperature. It is essential for all these operations to have a furnace capable of producing a very high heat, and the inventor states that the furnace which is best adapted for this work, is what is known as the Siemens regenerative open-hearth furnace.

678 The process does not bear the slightest resemblance to the Jones method: it simply consists in taking a batch of molten iron and treating it in an open-hearth furnace so as to change its chemical composition, or its temperature, or both, and bringing it to a predetermined standard suitable for use in the converter.

The description of the process does not indicate in any way an intention to retain in the furnace any considerable body of metal to be used in modifying the character of successive small additions poured into it. On the contrary, it consisted in dealing with separate and wholly distinct charges of metal; that is to say, the furnace is first to be charged with fluid metal, then this charge was treated or superheated, and finally tapped out. The empty furnace is then filled with a fresh charge, and the operation repeated.

The process is wholly different from the Jones method. None of the descriptions found in the exhibits gives any indications or suggestions which, in my opinion, would lead any one in the direction of discovering the Jones method.

Q. 7. Some of the defendant's witnesses have taken the ground that the Jones mixer is merely a reverberatory furnace, and there-

fore that the Jones invention is anticipated by the Durfee exhibits. What is your opinion with regard to this?

A. The theory that the Jones mixer is a reverberatory furnace seems to me to be absurd. A reverberatory furnace is a furnace which is intended to impart an intense heat to objects on its hearth by reverberation from its roof, the heating flame passing between the object and the roof. To say that the Jones mixer is a reverberatory furnace because it may be advantageous at times to introduce a small amount of flame into it to prevent undue chilling of the top of the metal is ridiculous.

A reverberatory furnace in the iron and steel business is a furnace intended to melt and otherwise treat metal, or to heat
679 metal to a high temperature for rolling, forging, etc. It requires the use of large amounts of fuel. The Jones mixer can be run under normal conditions without any fuel whatever for long periods of time, and because it may be advantageous to introduce a small jet of gas or oil under abnormal conditions to maintain the heat of the vessel, certainly affords no warrant for calling it a reverberatory furnace. It would be as reasonable to say that a transfer iron ladle, when a hood is placed on it and a jet of gas introduced under the hood to keep it warm during a long delay, was a reverberatory furnace; or that a room in which a lot of gas jets were lighted was a reverberatory furnace. The whole argument is simply a play on words.

Obviously, Durfee never thought of employing anything like the Jones mixer, which is not even provided with a chimney, and which could not be used to melt additions. Durfee's process would require a furnace which would produce a far higher temperature than has ever been dreamed of in connection with the Jones mixer, and he did not, in my opinion, anticipate the Jones mixer. It would be very expensive to treat the metal in an open-hearth or reverberatory furnace; the heating of the metal in such manner would burn out the silicon, and the process would, therefore, be inefficient and uneconomical. The unsuccessful experience at the Moss Bay works, where an open-hearth furnace was placed between the blast furnaces and the converter, as an intermediate receiver, and which was called by Mr. Snelus a step in the wrong direction, confirms me in this.

Q. 8. Please examine the Witherow U. S. patents Nos. 327,425 and 315,587, and state whether either of said patents discloses the Jones method.

A. The Witherow patent No. 327,425 shows a storage vessel used in connection with a single blast furnace, and the method of operation described is to tap a cast from the blast furnace into the receptacle, which is specified to be of such size as to hold a whole cast, and then to tap it out in portions of the right weight each
680 for a converter charge. Blow-pipe jets for maintaining the heat of the metal are introduced in such a way as to strike its surface; an arrangement which is faulty and impractical, as it would cause excessive oxidation of the metal. This apparatus was not intended to mix pig iron, but simply as a receptacle which would

hold a full cast from the furnace, the intention being to empty this cast by drawing off several portions into the converter, by the time the furnace is ready to make another cast, and thus avoid small and frequent tappings, the impracticability of which would, of course, be evident to the inventor, who is an experienced blast-furnace man, and is, indeed, pointed out in the patent.

This apparatus would afford absolutely nothing in the way of equalizing and averaging the quality of pig iron between successive casts, as one cast is drawn out before the next is put in, and each cast retains the same characteristics which it had when tapped into the receptacle until it is all tapped out into the converter. There is none of that blending and continuous gradual changing of quality and temperature of metal in the mixer, which is such a beautiful feature of the Jones method. This patent, in my opinion, does not disclose the Jones method, nor does it give any suggestion which would aid any one to arrive at the Jones method.

The method described in the patent to Witherow No. 315,587 is to tap the metal into the receptacle which will hold part of a cast, or a whole cast if necessary, and pour from this into the converter. This patent differs in no essential respect from the former one, except that no blow-pipe flames are blown in upon the surface of the metal, in which respect it is better. Like the other, it is not intended to mix the metal of one cast with that of another, and simply shows a storage receptacle to enable the furnace to be cast at proper intervals for successful working.

681 This patent does not, in my opinion, disclose the Jones method or anything akin to it, nor would it suggest to any one the Jones method.

Q. 9. Will you please read the depositions of William Whitney and others with reference to the foundry practice at the works of A. Whitney & Sons, of Philadelphia, and state whether you understand the practice therein described?

A. I have read the depositions and I understand the said practice.

Q. 10. Will you please state whether, in your opinion, the practice at the Whitney foundry was the same as the method of the Jones patent in suit, and whether from such foundry practice the Jones method would be obvious to those skilled in the manufacture of steel?

A. The practice at the Whitney foundry was not the same as the Jones method. Jones takes the crude liquid iron direct from the blast furnace and passes it through the mixer previous to refining it in the Bessemer converter to produce steel, carrying the metal through from the raw ore to the finished steel ingot, while fusing it only once. On the other hand, the Whitneys took cold metal of various kinds and from various sources, each kind being thoroughly tested to ascertain its special individual character. Having thus ascertained the character of each individual part of the iron they combined them in the proportions that their experience dictated, to make up the charge for the cupolas. In doing this they weighed out batches of two thousand pounds, each made of fifty pounds;

for example, of one kind of iron, one hundred pounds of another, two hundred pounds of another, three hundred pounds of another, etc. These drafts of iron were charged into the cupola in the usual manner and melted down and run by spouts into the receiving ladle which was so arranged that the three cupolas could be tapped into it at once, the cupolas being tapped simultaneously and at regular intervals, say fifteen minutes apart. From the receiving

682 ladle the iron was poured into small pouring ladles in the manner common in nearly all such foundries, and poured into molds for car wheels. A striking feature, which will occur to any one reading the description of this practice, was the extreme care and nicety with which the charges for the cupolas were made up, which is also described as the first step towards securing uniformity. While the receiving ladle used in the Whitney foundry would equalize the composition of the iron to a greater or less extent, I think that the entire operation of taking the cold iron, testing it, weighing it accurately, mixing it cold, charging it into the cupola, melting it, tapping it into the ladle and pouring it in small charges to make car wheels, bears but little resemblance to the Jones method. And I think a practice of this kind in which such extreme care is bestowed upon charging and melting down the metal in a cupola from cold iron would be the last thing in the world to suggest to a man to attempt to get substantially the same result without the use of the cupola. I believe that if Capt. Jones had had a car-wheel foundry in his works in which the Whitney practice was used he would have been less likely to have invented the Jones method. I have long been familiar with the methods of casting used in foundries, and I was for about two years in charge of the blast furnaces at Captain Jones' works while they were sending fluid metal direct to the converters, during which time I gave a great deal of thought to plans for bettering the direct process, and yet with all this the foundry practice never suggested the Jones method or anything of the kind to me.

There can be no doubt at all that many of the prominent managers of Bessemer steel works in this country prior to the date of the Jones patent were perfectly familiar with such practice in car-wheel and other foundries. In fact, the Lackawanna steel works followed the practice of tapping the different cupolas in their foundry into a receiving ladle in making castings. In most cases where foundry metal is tapped into a large ladle and then run off into small

683 ladles, I believe that the arrangement is adopted for convenience in supplying the large number of small ladles used in making the castings and that any mixing of the iron which may result is merely incidental. In the great majority of cases there is no attempt made to maintain a regular amount of iron in the ladle.

In the Bessemer practice with cupolas, the receiving ladles were arranged to receive the metal from several cupolas, being placed on the scales so that accurate weights could be poured into the converters. Some of these receiving ladles held a little more than a charge and some held as high as two or three charges, the object of

the large ladle being to allow the cupolas to be tapped at the regular time without interruption in case of some short stoppage to the converter. While it is now easy to predict by what might be called a skilled analogy-hunter's hindsight, that this ladle might under certain conditions cause a certain amount of equalization in the composition of iron tapped into it, yet I think it would be incorrect to say that this practice of using cupolas and receiving ladles in the old Bessemer works would suggest to any skilled steel-maker the idea of the Jones method of working without cupolas. And while the receiving ladle in the Whitney foundry undoubtedly did to a certain small extent equalize the composition of iron passing through it, I think the whole process is far removed from the Jones method and would tend to lead one away from rather than towards the latter.

Q. 11. Leaving out of consideration the facts mentioned by you in your last answer, and the fact that the Jones method and the Whitney Foundry practice belong to different arts, will you please state whether there is any true analogy between the steps of the foundry practice and those of the Jones method, and state the facts upon which your answer is based.

A. Assuming that the Whitney Foundry practice after the
684 metal is tapped from the cupola, starts at a point analogous to the point in the Jones method where the metal is tapped from the blast furnace, which analogy, however, seems to me to be untenable, we have in the Jones case the metal being tapped from the blast furnaces, each tapping being divided into several comparatively small portions which are poured into the mixer successively; while on the other hand, in the Whitney Foundry practice, we have three furnaces, assuming the cupolas to correspond to the blast furnaces in the Jones practice, which are tapped into the receptacle simultaneously. This method, it seems to me, is radically different from the one used by Jones, and a moment's consideration will show to any one that it is a method which could not be made a practical commercial success in Bessemer works. Even if blast-furnace apparatus were arranged to operate by the method practiced in the Whitney foundry, the results would not be at all comparable to those obtained in the Jones method, and would be open to all the objections of the Deighton type of practice.

It must be borne in mind that the cupolas in the Whitney foundry produce melted iron with a composition very close to that desired, whereas, the crude metal from the blast furnaces is liable to vary between wide limits, and at times to be entirely unfit to go into the mixer. If it were possible for the blast furnaces to produce metal even approximating in desired uniformity and closeness of composition to that furnished by the cupolas in the Whitney Foundry practice, there would be no need of using any mixer at all; so that it seems to me the two processes are not similar and that Whitney's practice does not anticipate the Jones method.

Q. 12. Leaving out of question the fact that the Jones patent deals solely with the mixing of metal taken from blast furnaces, and not with metal taken from cupola-melting furnaces, is there,

in your opinion, any analogy between the Jones method and the Whitney Foundry practice?

685 A. In my opinion, there is no analogy. If a steel manufacturer, seeing the Whitney plant, should conceive the idea that the same could be applied to a blast-furnace plant, for the purpose of preparing the metal for use in converters, his efforts would, simply result in the construction of an apparatus similar to that disclosed in the Deighton patent; that is to say, supposing he had three furnaces to correspond with the three cupolas of the Whitney plant, he would connect such furnaces with a receiving vessel of suitable size, by means of three spouts leading into one common spout, which in turn would empty into the receiver. Then, when the said three furnaces were in a condition to make a cast, he would, in analogy to the Whitney practice, open the tap-holes and run the entire cast of all three furnaces through the said spouts into the receiver. He would not attempt to change the natural operation of the blast furnace plant, and as blast furnaces are tapped once in four hours, he would fill his reservoir from the three furnaces only that often. It would not, in my opinion, occur to him, simply because the Whitney cupolas operating in the usual way were tapped more frequently, to correspondingly change the operation of the blast furnaces and tap the metal therefrom at any shorter intervals than was customary, because the cost of doing so would more than counterbalance any advantage which he would gain in the use of the receiver. In the meantime, during these long intervals between the casts from the blast furnaces, he would be drawing the metal from his receiver to operate his converters, and this would have the effect of causing the quantity of the metal in the receiver, supposing the number of converters served by the blast furnaces to be proportional to the capacity of the blast furnaces, to be reduced to a very small amount, if not entirely exhausted therefrom.

So that the application of the Whitney practice to a blast-furnace plant would not result in a use of the Jones method, or

686 in the obtaining of the advantages which accrue therefrom.

Q. 13. Do you find in the Whitney practice the additions of successive portions of metal in the mixing receptacle and taking away therefrom portions only without entirely draining the receptacle?

A. No; I do not. As I understand the word "portions," as used in the Jones patent, it refers to "portions" of a cast of one or more blast furnaces. In the Whitney practice the entire cast of all three cupolas is run together by means of the respective troughs leading from the cupolas into the common trough, and thence into the receptacle. So that we have, just as in the Deighton patent, the entire cast of not one, but several furnaces, which if applied to a blast-furnace plant and the crude metal produced thereby, would cause wide variations from time to time, both in the non-metallic constituents and temperature of metal in the receptacle. Of course, with a foundry plant such as Whitney's, where the cupolas are in the condition to tap every 20 minutes, the additions to the metal in the receptacle are more frequent, and the quantity thus supplied is

relatively much smaller than in a blast-furnace plant, but it cannot be assumed that a blast-furnace engineer in attempting to transfer the Whitney practice to a blast-furnace plant, would make tappings so frequent and so small in amount as was the case in the Whitney plant, and, indeed, this would be impossible. What he would do would be to do the same thing in the blast-furnace plant as was done in the Whitney plant, namely, tap the furnaces when they were full and ready to tap, and take the charges from the receiver to the converters when such charges were needed. When he would do this he would be doing in a blast-furnace plant exactly the same thing as was done in the Whitney plant, considering the natural construction and operation of that plant, with the result that there would be no balancing of the additions with the subtractions,
687 and there would be no securing of any gradual change in the composition and temperature of the pool of metal in the receiver.

Q. 14. How would you answer this question as applied to the practice of placing a separate vessel before each cupola and the cupola tapped from time to time into the metal in such vessel?

A. Of course, you ask the question assuming that the blast-furnace worker is to use apparatus of reasonable and practicable dimensions and kind. The practice of draining such vessel one-half or three-fourths before charging it, would result in such inequalities of Bessemer product, as to destroy all the possible advantages. The effect would be to dissuade from rather than to lead towards the use of a mixer.

Q. 15. Have you read, and do you understand Holley's 1877 report on the use of direct metal? If your answer is yes, please state whether you find in it a description of the Jones method, or anything substantially the same or analogous thereto?

A. Yes, I have read Holley's report on the use of direct metal, 1877. I do not find anything described in it substantially the same as the Jones method of mixing pig iron, or anything analogous thereto. He suggests mixing iron in a small reservoir or in a very large reservoir in the shape of an open-hearth furnace, but describes nothing different from what was indicated by the Durfee patents and letters, or the description of the open hearth furnace at the Moss Bay works, intended for storing iron. In no place does he indicate the plan of taking small portions of crude iron from a single cast, or from different casts of a blast furnace, and pouring them successively into a mixer; and it is significant that the open-hearth furnace which was tried at Moss Bay on the lines indicated in Holley's report was a failure, and was pronounced by Mr. Snelus to be a step backward. The Holley report, it seems to me, can only be taken as an expression of the opinion on the part of
688 Mr. Holley that there was a crying need for a practicable method of mixing iron in the Bessemer process.

Q. 16. Answer the same question with reference to Holley's description of cupola ladles in London Engineering of 1873; Holley's description of cupola ladles at Vulcan works, 1877, and the publication to which Mr Morgan, p. 611, refers as Snelus' discussion,

1871; Hunt's history, 1876; Bessemer discussion, 1876; Snelus on Fritz, 1878.

A. I have read the discussions mentioned, and find nothing in them which could be called a description of the Jones method.

Holley, in his description in the London Engineering *of* 1873, states that the use of the ladles is important in the following respects: First, that the cupola cannot be so economically worked if large charges have to be tapped at once. Second, it is necessary to weigh the charge between the cupola and the vessel. Third, several charges can be run into the ladle in case of delay to the converters, thus preventing the cupola from being dumped, and part of the day's work lost. In his description of the Vulcan works in the Engineering, 1877, he also gives as the advantages of the ladles that they form reservoirs, thus making the melting department and converting department independent of each other, within limits. He also says, that if any delay should occur in casting or from other causes, the melting department could keep right on, for these three ladles will hold, say, six vessel charges which may be stored and converted when the converting department is ready for them. In neither of these descriptions does he intimate that the ladle performs functions analogous to that of the Jones mixer. The ladle was arranged to enable the iron to be weighed, and also so as to give a reserve storage capacity, but there was no idea of carrying a constant body of iron in the ladle for the purpose of promoting uniformity between the successive charges. This was entirely
689 unnecessary with the old cupola practice, as is shown by the fact that many works, for instance the Monongahela and Jones & Laughlin's works, today use ladles between the cupolas and converters which only carry a single charge, and these works produce a uniformly high grade of metal.

It was usual to empty these ladles in charging the converters. There was no purpose in doing otherwise, and where the ladle was not entirely drained, no one recognized any benefit in mixing resulting from such practice, and indeed the practice was so occasional and the amount contained in the ladle so trifling that it would not have resulted in any substantial benefit, even if the cupola metal had not been so uniform already as not to have needed any equalizing. I am very familiar with the ladle practice, as we used it at the Edgar Thomson works, during my service there before the Jones mixer was installed.

At the time I was in charge of the Edgar Thomson furnaces and while direct metal was being sent to the converter works, I was quite familiar with Holley's 1877 report and fully alive to the desirability of doing away with the evils of direct metal, but I must say that this did not suggest to me the method subsequently devised by Jones. If this method had been obvious, from the report, to a skilled steel-maker I think I would have seen it. If the method had been obvious to Holley, his relation to the steel-makers was so intimate and their confidence in him so unbounded that if he had said to them that he saw a way which he considered practicable they would have instantly proceeded to develop it. He was con-

sulting engineer for the Bessemer Steel Association, which included nearly all the Bessemer works in this country, and received a very large salary for advising them in just such matters. His habit was to patent all his inventions relating to the Bessemer process, and I feel sure that if he had made this invention he would have patented it. I have examined his patents and find that he did not do so.

690 Q. 17. The defendant's witnesses have testified that at their works all the crude metal from the blast furnaces is stored in the mixer, and that the metal from the cupolas is not put in the mixers, except a small proportion occasionally. What would you say as to the reason for this?

A. The reason for not putting the cupola metal in the mixer is, that it is not necessary, cupola metal being sufficiently uniform without mixing. They put all the blast-furnace metal through the mixer, in my opinion, because it is necessary to do so to get sufficient uniformity of heat and composition.

Q. 18. In the operation of blast furnace is it commercially practicable either to make small and frequent tappings, or to stop the flowing of the metal before the furnace is drained?

A. No. I do not consider it practicable to cast oftener than once in every four hours, nor to stop the tap-hole until the hearth is drained.

Q. 19. Do you regard the defendant's mixer, as described by the witnesses, as being in any sense a reverberatory furnace?

A. I do not. I understand that the defendant's mixer is a large vessel, at the spout of which a gas flame is introduced to prevent undue chilling in the spout. There is no reverberatory action, no high heat created, no melting of metal.

Q. 20. Will you now state what was accomplished by the Jones method which was not accomplished by the prior practices and plans which you have discussed in your deposition, and in what respect, if any, the art has been advanced by Jones?

A. The Jones method has made the direct process, which was attended with great dangers and difficulties before the date of his invention, a thoroughly practicable and successful one. Instead of it being a question of great doubt whether to run the metal

691 direct to the converter or remelt it, as it was up to the time of Jones' invention, no one would now think of building a new works, containing both furnaces and converters, without arranging to mix the metal by the Jones method which not only effects an immense saving in the cost of operating the works but enables a uniformly good product to be made, and also a purer product than can be obtained from cupola metal which absorbs and is contaminated by sulphur from the coke which constitutes the fuel of the cupola.

I remember that before the installation of the first Jones mixer, after studying the results which had been obtained at the Edgar Thomson works and elsewhere in the use of the direct process, I consulted with Mr. James Gayley, and we agreed that in the building of a new works it would not be profitable to use direct metal,

but that on the contrary the disadvantages resulting from irregularity in the product were so great that it would be better to go to the expense of building and using cupola furnaces. We did not then perceive any means adequate to overcome these disadvantages.

Jones' invention has solved a difficulty and met a great want which has been felt ever since the invention of the Bessemer process in 1856, and has enabled that process to be used with direct metal, as Bessemer first proposed to use it. Bessemer, however, failed in his efforts to overcome the difficulty, and from that time many metallurgists and inventors have sought to solve the problem, but without success until Jones made the invention in suit.

692 PITTSBURG, *March* 30, 1897.

Met pursuant to agreement of counsel.

Present: Bakewell & Bakewell and Mr. Thomas B. Kerr for complainant; Mr. James I. Kay and Mr. P. T. Dodge for defendant.

Complainant's counsel states that at the hearing of the cause he will urge infringement of the second claim only of the patent in suit.

Defendant's counsel gives notice that prior to the hearing of the cause, defendant will move the court to strike from the record all the depositions or parts thereof as to the manufacture of steel, or the preparation of the crude metal therefor, or as to the non-use of methods of steel manufacture, or the preparation of crude metal therefor, before or after the invention involved in the patent in suit, outside of the United States, on the ground that the same is not admissible under the statute, and is immaterial; and if such evidence is permitted to stand on the record, notice is given that motion will be made to take rebuttal testimony in answer to the same.

Cross-examination by defendant's counsel:

X Q. 21. During what years were you employed at the Edgar Thomson steel works?

A. From 1879 to 1884.

X Q. 22. During that time you had entire charge of the management of the blast-furnace department of those works. Is this correct?

A. Yes.

X Q. 23. And from 1884 to 1887, you occupied the same position in connection with the Lucy furnaces, which then belonged to the same company?

A. Yes.

X Q. 24. Had you prior to 1879 any knowledge of the operation of blast furnaces, and if so, how early and in what way was it obtained?

693 A. In 1869 I worked on the construction of the Struthers Iron Company's furnace at Struthers, Ohio, assisting in the making of the drawings, and also working around the plant as helper to machinists erecting machinery. After the erection of the furnace, I had charge of the machinery on one turn for one year;

was then for a few months foreman in charge of one turn, and also for a few months in the office as shipping clerk. After this I went to college. After leaving college I had charge of the furnace of the Brier Hill Iron & Coal Co. for about a year, which makes up my experience previous to going to the Edgar Thomson furnaces.

X Q. 25. Had you prior to going to the Edgar Thomson works, obtained any knowledge of the manufacture of Bessemer steel?

A. Not in a practical way. I had read about it and studied the theory of it in my college course, but I had not been engaged in a Bessemer works until that time.

X Q. 26. How many blast furnaces did they have at the Edgar Thomson works when you had charge of that department?

A. Five.

X Q. 27. Were they all located together?

A. Yes.

X Q. 28. Was each one of these furnaces operated independently of the others?

A. Yes, I should say they were. There were some things common to all of them; one day foreman and one night foreman had charge of all of them, and three of them worked with one common battery of boilers; the other two having their own common battery independently of the others.

X Q. 29. I presume that they utilized the gases from the blast furnaces in each group for generating the steam in the battery of boilers common to that group?

A. Yes.

694 X Q. 30. Were the furnaces tapped independently of each other?

A. Yes.

X Q. 31. That is, you paid no attention to the time of tapping one furnace and tapping another furnace, either in its group or the whole five furnaces?

A. We generally tapped at the same time on the four larger furnaces; but there were times, of course, when tappings would be delayed on one furnace, and this had no effect on the others.

X Q. 32. About how often was it the custom to tap these furnaces?

A. Every six hours.

X Q. 33. When you first went there, all the metal made in the furnaces was cast into pigs, I believe?

A. When I first went to the Edgar Thomson, they had just broken ground to build the blast furnaces. When they started the metal was all cast into pigs, until the direct process was started there, which, I think, was in 1882.

X Q. 34. About when did you commence making pig metal there?

A. I can't fix the exact time; it was early in 1880, possibly February.

X Q. 35. What was the custom when they cast the metal all into pigs as to obtaining analyses of the pig metal produced?

A. Analysis was made of each cast for silicon; sulphur was de-

termined in nearly every cast, and phosphorus occasionally; manganese was also occasionally determined.

X Q. 36. Your custom as to silicon was to take a boring of one of the pigs of each cast and send that to the laboratory to be analyzed. Is this correct?

A. We generally took the borings from two pigs of different parts of the cast, and mixed them; sometimes we granulated the
695 iron by pouring it in water and sent a sample of this to the laboratory. This, I think, we did after we commenced to run direct.

X Q. 37. When you commenced to run direct, what was your custom as to tapping the blast furnaces and supplying the metal to the converter? Please describe the manner in which you provided a practically constant supply for the converters.

A. We ran in a train of 5 or 6 ladles to a furnace, tapped the furnace, and filled the ladles; after which we ran the remainder of the cast into the pig beds. This train of ladles was then hauled by a locomotive up to the Bessemer works and the metal poured into the converters. Sometimes we ran the ladles about half full at one furnace, then hauled them around to a second and filled them up, and then took the train up to the Bessemer works.

X Q. 38. You have not entirely answered the question. I want to know how you arranged the tapping of your furnaces to provide a constant supply to the converters so that they could run continuously.

A. When the furnaces were all making good iron, we tapped them alternately as nearly as we could so as to send the iron as uniformly as possible up to the converter works.

X Q. 39. That is, you timed the tapping of your five furnaces so as to make the tappings successive, and in this way keep up a regular supply for the converters?

A. We had one small furnace which ran mostly on spiegel or ferro-manganese, but the other four we tried to arrange in the manner you have indicated, tapping them sometimes as often as once in four hours each, which was about as short a cast as we found we could make. Sometimes when one furnace was on cold iron and another on extra hot iron, we tapped these two close together, mixing the iron in the ladle.

X Q. 40. How would you know that one furnace was on a hot iron and the other on a cold iron?

696 A. By the general working of the furnace, it was possible to judge in a general way about what the character of the iron would probably be, at least to the extent of knowing that one was producing iron too cold to use alone and another iron with considerable excess of silicon over what was needed to blow in the converter.

X Q. 41. By "cold iron" you mean iron too low in silicon, and by "hot iron" you mean iron too high in silicon. Is this correct?

A. This is correct, though in addition to this the iron which was very low in silicon was very often low also in temperature. The amount of silicon present, however, was the principal factor in de-

termining the heat at which the iron would work in the converter. Iron low in silicon, due to variations in the working of the furnace, was also apt to be high in sulphur.

X Q. 42. For information of the court, please state generally the way you had of determining the condition of the iron as to whether it was high or low in silicon or in temperature before the cast was made?

A. In a general way, it is judged whether the furnace was running at about the same temperature it had been, by the appearance of the slag tapped off at intervals, by the appearance of the furnace as seen through the tuyeres, by the blast pressure in the engine-room, and by the appearance of the gases at the chimney tops. Knowing the analysis of the preceding cast, a person carefully watching the operation of the furnace could judge in a general way whether the next cast would probably be about the same in silicon, or whether it would be lower or higher. His judgment would necessarily be more or less crude and his forecast only approximate, but in a general way he could form a fair idea of the character of the iron before tapping it.

X Q. 43. Were there any indications from the metal itself as tapped from the furnace as to its silicon content and temperature?

697 A. Yes, the metal flowing from the furnace would show whether it was hot or cold in temperature, and a person could tell from the appearance of it while flowing whether the silicon was very low. With higher silicon, however, it would not be possible to judge from the appearance very closely what the amount was. It is also customary to cast a little of the iron into a chill, and the fracture of this piece served to indicate the amount of silicon to a certain extent. This fracture test would indicate pretty closely in case of very low silicon, but would not give so close an indication in case of higher silicon.

X Q. 44. I presume these means of determining the character of the metal indicated to you whether it should be sent to the Bessemer works or cast into pigs?

A. Sometimes they did; for example, if the iron was white it would not be fit to go to the Bessemer works. By white iron I mean iron which shows a silvery-white fracture when broken through a pig, such iron as a general rule being very low in silicon and very high in sulphur. If, however, the iron was about on the border line between iron which could be used in the Bessemer, or which ought to be rejected according to the specifications, the tests I have mentioned would none of them determine the matter with certainty.

X Q. 45. When you were using direct metal at those works, you had the runners from each furnace arranged so as to direct the metal either into the ladles to be carried to the converters, or into the pig bed?

A. Yes.

X Q. 46. And you could change the course of the metal to lead it in one direction or the other by means of a dam?

A. Yes.

X Q. 47. In filling the ladles with the molten blast-furnace
698 metal, did you first fill one ladle and then direct it into another, or did you subdivide the stream and have it flow into all six at one time?

A. This, as I remember, depended on the speed which the iron came. I think we generally had it running in more than one at a time, and possibly sometimes we might have it running in all six. We always tried to have one ladle filled in advance of the others so as to cut them off one at a time by a gate in the runners.

X Q. 48. Were you acquainted, when you were at those works, with the manner in which they tapped the metal from the cupolas in preparing the charge for the converters, prior to the time that they used direct metal?

A. Yes, I have often seen them tapping metal from cupolas.

X Q. 49. How many cupolas did they use?

A. I think three.

X Q. 50. And they tapped those three into a single charging ladle, did they not?

A. Yes, sir.

X Q. 51. Did they tap them simultaneously or successively?

A. Generally simultaneously, or approximately so.

X Q. 52. Did it ever occur that they tapped them successively?

A. I presume it may have. The general practice was to tap them at the same time or about the same time.

X Q. 53. And the metal from the three cupolas would pass down the runners into the charging ladle and mix there, would it not?

A. Yes.

X Q. 54. About how much metal did each one of the ladles filled at the blast furnace and carried to the converter generally hold?

A. Ten tons.

X Q. 55. How do you differentiate between the first and the second claims of the Jones patent in suit?

699 A. I have not studied the first claim of the Jones patent in suit, and have made no attempt to differentiate between them.

X Q. 56. Did you not read the whole patent before testifying?

A. Yes.

X Q. 57. I wish you would now read the two claims, and considering them as an engineer, would state how you distinguish the one from the other?

(The question is objected to by complainant's counsel as improper cross-examination, and as incompetent.)

A. The patent describes a method of mixing metal cast from a blast furnace by taking small portions of the different casts and mixing portions taken from different casts, which I suppose is described in the first claim.

The second claim I judge to describe a particular method of mixing these proportions, by introducing them successively into a mixing receptacle, at the same time drawing out portions from this

receptacle in such a way as to maintain therein constantly a considerable body of liquid crude metal.

X Q. 58. Then the main difference between the first and the second claims of the patent resides in leaving metal in the mixer?

A. The first claim makes no mention of a mixer, and I suppose the second claim is intended to describe the method used with the apparatus shown in the drawings of the patent, and I judge that the first claim is intended to be more general.

X Q. 59. Does the main difference between the two claims reside in the second claim providing for leaving metal in the mixer when the charge is withdrawn?

A. No; I should think a still more marked difference would be the fact of its calling for a mixer or mixing receptacle.

700 X Q. 60. How could you practice the method in the first claim without employing a mixing receptacle?

A. The inventor states in the specification, page 1, line 82, "My invention may be practiced with a variety of forms of apparatus; for example, by merely receiving in a charging ladle a number of small portions of metal taken from several ladles or receiving vessels containing crude metal obtained at different times or from different furnaces." This method would, I think, answer the purpose, with the exception that of course any charging ladle might be called a mixing receptacle, but of course it would not be the mixing receptacle shown in the drawings of the patent and which I take to be referred to in the second claim. If we tap 3½ tons of metal each from three cupolas into a ladle, we might say that this ladle allowed this iron to mix. If we pour this iron from the ladle into a converter, we shall not have accomplished any good result by the mixing, and no better product will have been obtained from the converter than if we had tapped each cupola into a separate ladle and emptied the three into a converter at once. In other words, there is no object in thoroughly mixing a single charge before putting it into a converter.

X Q. 61. Would the method of mixing in a charging ladle, which you have just described, be covered by the first claim of the Jones patent?

A. I should think not.

X Q. 62. Why not?

A. I take the Jones process to be one for equalizing the metal in continuous running in the refining of iron, and not for equalizing the composition of the metal in the different parts of single charge about to be poured into the converter, which would be manifestly useless. I take it that the inventor aimed at obtaining uniformity as nearly as possible between the successive charges, which is a very desirable thing to accomplish.

701 X Q. 63. Would this rule which you have just stated apply, in your opinion, to both claims of the Jones patent?

(Counsel for complainant objects to all this line of cross-examination for the reason above stated.)

A. I think the object of the Jones patent throughout is to avoid

wide differences between successive charges placed in the converter, rather than the mere mixing of a single charge to obtain uniformity in all parts of a single ladleful about to be poured into the converter, which uniformity would be of no practical advantage.

X Q. 64. Do you find any distinction in the two claims of the patent in the use of the words "iron directly from the smelting furnace" used in the first claim, and the words "molten metal" used in the second claim?

A. I take these expressions to be interchangeable, or both to refer to the same thing, that is to say, the liquid metal tapped from the blast furnace.

X Q. 65. Does not the term "molten metal" include any molten metal, whether obtained from a blast furnace or other source?

A. I think not in this connection. Broadly speaking, of course molten metal would mean any kind of metal in a melted condition, such as melted lead or Babbitt metal, in fact, any metal that could be named. I imagine the term in the patent, however, means molten pig iron from a blast furnace.

X Q. 66. The term molten metal in its general sense would, of course, include molten pig metal which was remelted in the cupola?

A. Yes, if used broadly, I suppose the term "molten metal" would cover any kind of melted metal, no matter how the melting may have been performed.

X Q. 67. Such molten pig metal remelted in the cupola would be similar to the blast-furnace metal, in that it contained silicon, sulphur, carbon and other metalloids, would it not?

702 A. Yes; both pig metal remelted in the cupola and crude metal from the blast furnace contain more or less of these elements.

X Q. 68. Considering that the first claim is limited to iron directly from the smelting or blast furnace and the second claim uses the broader term "molten metal," would not a reasonable understanding of the second claim make it include in this term "molten metal" the pig metal remelted in the cupola?

A. From the fact that the invention is stated in the specification to be intended to remedy the trouble due to the lack of uniformity in the metal tapped from blast furnaces, and thus do away with the troubles incident in taking the metal direct from the blast furnace to the converter without the use of a cupola, I think that there can be no doubt that the term "molten metal" was meant to describe raw iron from the blast furnace, especially as the successive portions are described as being ununiform in sulphur, silicon, &c. It will be noted that the specification speaks very particularly of the variation or lack of uniformity in metal tapped from blast furnaces. I am confirmed in this opinion by the fact that metal taken from cupolas is, if the operation is carefully carried out, amply uniform for further treatment in the steel works.

X Q. 69. Would not the pig metal which would be cast into pigs

from the blast furnace be likewise ununiform in its contents of silicon, sulphur, &c., just as much as if it were run into a ladle?

A. Yes. The same variation would exist in the pig metal as in the fluid iron.

X Q. 70. And if this pig metal were introduced into the cupolas without selection, just as it was received from the blast furnace, would not the resultant cupola metal from several cupolas also be ununiform in its contents of silicon, sulphur, &c., one as compared to the other?

703 A. Not necessarily. Fifty tons of a certain iron might arrive from the blast furnaces having been made in one cast and be charged into the cupola without causing any noticeable difference in the iron from different cupolas. Of course, if a single cast from one blast furnace very low in silicon was charged into one cupola and another batch of iron very high in silicon charged into an adjoining cupola, we should have a difference in the iron coming out approximately the same as that going in, and if low silicon should be charged into a group of cupolas for six hours, and then followed by high silicon metal, we should have a great variation in the composition of the iron tapped out. This, however, is not the way cupolas are run in well-managed establishments.

X Q. 71. Would you practice the method of the second claim of this Jones patent if you followed the steps set forth and employed a reverberatory or heated furnace for the mixing receptacle?

A. If the furnace be made large enough to accomplish the same result in the way of retaining constantly a comparatively large amount of metal, and if it can be operated so as not to cause any abnormal change in composition in the metal placed in it, I should think we should be using the method claimed in the second claim.

X Q. 72. Suppose you employed for the purpose a furnace having a capacity of 60 tons, in which that amount of metal was stored or kept hot and followed the course set forth in claim 2, would you practice the method of that claim of the patent?

A. Assuming that the furnace was suitably constructed to allow the metal to be poured in and out in a practicable manner, I should think we would be following the method of the second claim.

X Q. 73. You refer in your third answer to the use of small portions of metal tapped from one blast furnace or from several blast furnaces. Will you please state the maximum and the mini-

704 mum weight which you believe would be included within such term as charges to be introduced into the mixer in practicing the method of the second claim.

A. I do not think that any hard and fast rule can be formulated for this. The minimum amount taken out of the mixer at a time would naturally be one charge of the converter. The amount poured in might be less than this, and the less the charge poured in, the better within reasonable limits, and the portions added between successive withdrawals of the charge might be greater than the amount of the charge. I should think to get good work from the process as a general rule there should be as much left in the vessel before filling as was added to it at one time. This, of course,

would depend somewhat on circumstances. If the iron was running very regularly from the blast furnaces there would be less necessity of keeping a relatively large amount in the mixer. With the furnaces running very irregularly, it would, of course, be better to keep the mixer as full as possible. The actual practice of the inventor seems to have been to add and withdraw portions of about 10 tons, and to retain in the mixer from say forty to eighty tons, as circumstances might call for.

X Q. 74. You have not answered my question. I would like to give you the maximum and minimum weight of the small portions to be introduced into the mixer, so that we can understand what is meant by your third answer.

(Complainant's counsel submits that the question has been fully and fairly answered.)

A. I think the minimum weights would be fixed entirely by the matter of convenience. Thus in taking iron from furnaces casting 50 tons and passing it through say a 200 ton mixer, there would, I think, be no object in putting in smaller portions than say 10 tons. We probably get as much light on this as can be obtained from the fact that the practice of the inventor was to use 10-ton portions with a 100-ton mixer. I should suppose that the ratio of one
705 portion to the capacity of the mixer might be increased, but I could not say just how much. If the mixer were drained down and only contained say 5 tons out of a hundred, and then had, say, 90 tons added, I should think this would be outside of the method, but just where the line would be I could not say. I should take it to be at a point where there would be no substantial benefit in obtaining uniformity or gradual change in composition of successive charges drawn out from the mixer.

X Q. 75. Referring to your definition of the method of the second claim in answer 3, especially the first sentence thereof, is it your understanding that the claim is limited to taking only portions of a single cast or casts from a blast furnace or furnaces?

A. The practice of the inventor was to take portions of casts, these casts running say from 50 to 60 tons and the portions having say 10 tons in them. I find nothing in the claim, however, specifically limiting it to this precise method. The object of taking these portions of casts was evidently to be able to make the additions comparatively small in proportion to the amount of metal held in the mixer all the time, and to alternate the metal oftener than if a whole cast had been put in at once.

X Q. 76. Well, does this second claim, in your opinion, cover the method of mixing where an entire cast from a blast furnace is introduced into the mixing receptacle at one time, the other steps being the same as stated in the claim?

A. I should think it might under certain conditions, but I do not think it would in a case where, for example, the mixer had a capacity of 100 tons and was operated in connection with furnaces cast in 50 to 60 tons at a time, as the additions would become so large as to cause the composition of the charges withdrawn from

the mixer to fluctuate very rapidly in case of wide variation in the metal going in. Under ordinary conditions, the process seems to work much better where large casts are divided into portions.

706 X Q. 77. Suppose that the entire cast or tap from the blast furnace were from 8 to 12 tons, would that be such a portion as would be included in the second claim, if the entire tap were fed at one time to the mixer?

A. With a 100-ton mixer I should think this amount would be a fair-sized portion, and I think might be included in the claim.

X Q. 78. Would it be included in the claim if you employed a mixer of only 50 tons?

A. I should think it might.

X Q. 79. Assuming the same charge and the same sized mixer, is it immaterial whether the metal is conducted from the furnace to the mixer by a ladle or by other means?

A. I suppose so, providing, of course, the means are good practical ones.

X Q. 80. So far as the vessels themselves are concerned, what distinction, if any, do you draw between the mixing receptacle of the second claim and the "charging ladle" of line 84, page 1, of the patent, where both vessels are employed for mixing the metal?

A. A mixing receptacle is a large vessel containing always considerable fluid metal, charges are drawn from it and it is replenished, and in this way causes a slow and gradual change of the composition of the metal drawn from it; whereas the vessel of line 84 is simply a charging ladle, into which a number of small portions of metal taken from several ladles or receiving vessels can be poured. This ladle is then emptied and another mixture made up of small portions placed in it, no metal remaining in it to affect the composition of the metal of the next charge.

X Q. 81. And you do not think that the method of the second claim as described in the patent can be practiced in this charging ladle?

A. Assuming that this ladle is adapted to only hold a charge, I should think not.

707 X Q. 82. How then do you explain the language of the patent, page 1, lines 82–85, "To this end my invention may be practiced with a variety of forms of apparatus—for example, by merely receiving in a charging ladle a number of small portions of metal"?

A. I think if a cast from one furnace be placed in a large receiver, and a cast from another furnace in another large receiver, and a third in another, if a charging ladle then be brought to this row of receivers and a small portion from each placed in it, that this would be the method described in lines 82–90. The inventor, however, does not consider this as good a method as to employ a large mixer with successive small additions and subtractions, though the former method could be so operated as to produce results analogous to those in the method which he prefers.

X Q. 83. It was a known fact prior to the erection of the Jones mixer at Edgar Thomson, that charging ladles were in use at some

of the Bessemer works in the United States, having a capacity of about double the converter charge, was it not?

A. It was.

X Q. 84. Well, considering this fact, is it not a fact that the patent in suit treats the charging ladle and the large vessel illustrated in the drawing as equivalent means of carrying out the Jones invention? Please read the patent carefully before answering the question.

A. No, it is not the fact. In one case, he fills a charging ladle with a number of small portions of metal taken from several ladles or receiving vessels containing crude metal obtained at different times or from different furnaces. In the process which he prefers, he uses the same charging ladle, but instead of filling it by the use of small portions from several receiving vessels, he fills it from one large mixing vessel, which has been operated in a peculiar way which he describes. There is not the least hint of interchangeability between the charging ladle and the mixing vessel.

708 Adjourned to meet Wednesday, March 31, 1897, at 10 a. m.

PITTSBURG, *March* 31, 1897.

Met pursuant to adjournment.

Present, as before.

Cross-examination of Mr. KENNEDY continued:

X Q. 85. Where in the specification of the Jones patent do you find the statement that the charging ladle is "emptied and another mixture made up of small portions placed in it, no metal remaining to affect the composition of the metal of the next charge," found in your answer 80?

A. I do not find this stated in the patent in so many words, but I think it fair to assume that the charging ladle was entirely emptied, inasmuch as nothing is stated to the contrary, and this has been the practice of the inventor with charging ladles worked in connection with the mixer. He also states that in this case the mixing is performed merely by pouring into the charging ladle, and I think he would have undoubtedly mentioned the fact if he had intended to maintain a pool of iron in this charging ladle.

X Q. 86. Referring again to the claims of the patent, what step is required in the second claim that is not required in the first?

(Complainant's counsel objects to this line of cross-examination, in that it is incompetent and involves a waste of time; the witness is one who is highly skilled in the art to which the patent relates, but he has not been offered as an expert in the construction of patent claims. The meaning of the first claim, moreover, is not now relevant to the issues of this cause.)

A. The second claim requires successive portions of molten metal to be introduced into a mixing receptacle, from which a portion only is withdrawn without entirely draining or emptying the same. This specific method of procedure is not called for by the first claim.

709 X Q. 87. What step or operation is there in the second claim which is not found in the earlier patents or publications quoted by you or referred to in your direct examination?

A. The operation described by the entire claim I presume, that many of the individual operations which go to make up the operation described by the claim are old in the art.

X Q. 88. What individual step or operation stated in the claim is not found in any of the earlier patents or publications quoted by you or referred to by you?

A. I don't know that there is any individual step or operation described in this second claim which is not found in some of these prior publications.

X Q. 89. In the operation of the invention described in the patent, is there any fixed number of portions or charges which must enter into the mixer to produce a proper mixture of the metal?

A. No.

X Q. 90. I presume this then depends on the quality of the several charges, their size, and the size of the mixer?

A. I should think that these would all be factors in the case.

X Q. 91. Well, are they not the controlling factors?

A. I should think the principal factor would be the number of charges which are retained in the mixer. Other things being equal, of course the size of the mixer would depend upon the size of the charges. The number of charges which it would be good practice to retain constantly in the mixer would depend upon the regularity and composition of the iron coming from the furnaces, as well as upon the amount of variation between successive charges permissible in the converting works.

X Q. 92. And in working a small plant you would therefore employ a correspondingly smaller mixer?

710 A. If by small plant is meant one with small converters or using small charges, the mixer could properly be made smaller than where larger charges were used, other things being equal.

X Q. 93. How would the mixing of molten pig iron from the blast furnace to secure an average metal differ in principle from the mixing of molten pig iron from the cupolas to secure an average? I refer to the mixing alone, and not to any other step before or after.

A. As far as the mere operation of mixing two or more portions of metal together to secure an average is concerned, I suppose the general principle would be the same whether we mix metal from the blast furnace, metal from the cupola, or sugar. In any case, we put together two portions of material and get a mixture having certain characteristics, an average of those in the component parts.

X Q. 94. In each case stated in the above question, that is blast-furnace metal and cupola metal there would be a mingling of the metals and an averaging of the silicon, sulphur and other metalloids contained in the metal would there not?

A. Yes.

X Q. 95. What is found in the Jones patent referring to the equalizing of the temperature of the metal?

A. I find nothing referring to this.

X Q. 96. Please quote from the Deighton English patent, No. 3672 of 1873, the language stating that all the blast furnaces are tapped simultaneously into the receiver.

A. I find nothing in the Deighton patent with reference to the time of tapping the blast furnaces.

X Q. 97. Were you at the Moss Bay works at Workington, England, during the use of the heating furnace mentioned in your answer to Q. 5?

A. No.

X Q. 98. Please read from the Durfee patents or publica-
711 tion the statement to the effect that the charge after treatment was "finally tapped out," and that "the empty furnace is then filled with a fresh charge and the operation repeated," as found in your answer to X Q. 6.

A. Durfee in his letter to Engineering, 1874, states "I propose to erect at some convenient place, as near as possible to the converter, one or more gas-reverberatory furnaces of sufficient size to hold the average tap of the blast furnaces, supplying the metal for conversion, and then run or pour the crude metal from the blast furnaces into these gas furnaces, where it could be alloyed or treated as desired, and thence be tapped out from time to time as required by the converting operation."

It is manifest from this description that the furnace would be tapped empty or very nearly so before another cast would be tapped in from the blast furnace.

X Q. 99. You referred to the desired uniformity for the blast-furnace or other crude metal for use in converting into steel by the Bessemer process. Within what range would you consider the metal uniform for this purpose?

A. Uniformity is a relative term. What is wanted in Bessemer practice is not so much that the silicon, for example, in the metal shall always be the same, as that it shall vary slowly and regularly between successive changes. Metal can be used in the converter having all the way from 1 per cent. to 2½ per cent. of silicon without serious trouble, providing the change is made gradually so as to allow the blower and scrapper to work intelligently. A very noticeable difference between Durfee's scheme and that of Jones' is that the former, by treating the metal in an open-hearth furnace, proposed to control its composition, while Jones made no attempt in this direction at all, but simply arranged to cause the variation of the metal to be rendered gradual instead of abrupt.

X Q. 100. Between the years 1875 and 1888, the proportion of silicon considered desirable in the crude metal for conversion was higher than it has been in late years, has it not?

712 A. Probably a trifle higher. The faster the converting works run, the lower the silicon can be, and where scrap is used up by open-hearth furnaces, the call is gradually for somewhat

lower silicon than where considerable scrap has to be worked in the converter.

X Q. 101. During those years from 1875 to 1888, the crude metal was converted having as high as 3 per cent. of silicon, was it not?

A. Yes. Pig metal as high as 3 per cent. was converted, scrap being used with it as a general rule to reduce the temperature.

X Q. 102. Was as great uniformity in crude metal for Bessemerizing required as was required in the cast metal for casting car wheels, such as in the Whitney practice?

A. No. In the Whitney practice, or any other practice for casting car wheels, the metal should be kept very close to a given percentage of silicon all the time; whereas in the Bessemer process, it is permissible to vary this through a wider range, but it is not permissible to make sudden changes from extreme low silicon to extreme high silicon. In some other elements, for example phosphorus, a greater variation would be permissible in making car wheels than in making Bessemer steel. The two arts are widely different in their requirements as to raw material.

X Q. 103. Assuming that the iron from the blast furnaces was all suitable for the converters, would not a large intermediate vessel to receive this metal be valuable and advantageous as a storage reservoir to allow the continuous working of the furnaces and converters?

A. Yes, I think that aside from any benefit that might be obtained as a mixer there might be some advantage in having a large storage reservoir between the furnaces and converters. The advantage, however, would be very small as compared with that due to the equalizing effect in the case of the Jones mixer, for example.

713 X Q. 104. During the time that you were at the Edgar Thomson works, and they were operated by direct metal, did you have any difficulty in regard to the weights of charges to the converters?

A. No serious difficulty. We could not get the weights as accurately as where a charging ladle stands on a scale while being filled, but they ran fairly close to the converter works. We had one man whose entire work was to judge of the amount of metal in the ladle, and he became quite expert at it.

X Q. 105. When they were using cupola metal at the Edgar Thomson works did they not have a scale in front of the converter so as to weigh the charge that was introduced into the converter?

A. Yes. They weighed the ladle while they were pouring into the converter, and did this also in the case of the direct metal.

X Q. 106. Supposing the entire casts from the blast furnaces were delivered into a mixer of from 250 to 300 tons capacity and mixed therein, and that this metal was drawn out in converter charges until the mixer was empty, would this be within the limits of either claim of the Jones patent, and if so, which one?

A. I do not think that this method would be within either claim

of the Jones patent. I am quite sure that it would not be within the second claim.

X Q. 107. Why would it not be within either claim?

A. It could not be within the second claim because it does not comply with the condition of leaving a certain amount in the mixer, and while the first claim is somewhat general in its terms I think it is meant to describe a process operated so as to obtain the same continuous and gradual change of composition that is obtained by the method specifically described in the second claim. In the example given where a cast is tapped into the reservoir from each furnace, there would be an equalization of composition
714 in this one batch of metal which would all be used up, and a fresh lot run in which would also be uniform throughout itself, but might vary considerably from the previous lot.

X Q. 108. Does the addition of several portions of crude metal successively, instead of introducing the same metal continuously or in a single operation, form an essential step in the Jones method?

A. No. If it were practicable to keep the metal running continuously in this mixer in a small stream, it would answer every purpose which is accomplished by putting in separate ladlefuls, thus, assuming, of course, that the quality of the iron poured in from time to time would be the same as if it had been put in with ladles. By drawing the iron out in the ladles, it is possible to alternate small portions from various casts, which it might be very hard to do if it were attempted to supply the iron in a continuous stream. Other things being equal, however, the operation would be practically the same with the iron flowing in continuously, as if it were added in detached small proportions.

X Q. 109. By a ladle is an old and the only practicable means for transporting molten metal between widely separated points?

A. Yes, a ladle is the only practicable means for transporting metal long distances, and is an old means for this purpose.

Redirect examination by Mr. BAKEWELL:

R. D. Q. 110. Will you state whether an ordinary reverberatory furnace, or a furnace such as is shown in Z. S. Durfee's U. S. patent No. 114,277, dated May 2, 1871, the application for which was filed on February 15, 1871, constitutes a practical or economical means for the practice of the method stated in the second claim of the patent in suit.

(Objected to as immaterial.)

A. No. I think a furnace such as shown in the patent
715 would not be suitable for practicing the method described in the second claim of the Jones patent; nor do I think that any of the ordinary types of reverberatory furnace would be suitable for it. Of course, such furnace might be transformed into one which would be much better, but the ordinary furnace I do not think would ever be a success if used for that purpose.

R. D. Q. 111. Will you state briefly some of the reasons for your last answer?

A. The pool of metal is wide and shallow in the furnace in question, exposing large surfaces to the air or flame as the case may be, and if much heat is used there is a tendency to change the chemical composition of the iron on account of this large surface, which I think would cause the furnace to be very unsatisfactory as a substitute for the mixing vessel such as used by Jones.

(Complainant's counsel offers in evidence a certified copy of the patent of Durfee, No. 114,277, dated May 2, 1871, for an improvement in the manufacture of iron and steel, the certificate attached to said letters patent certifying to the fact that the application therefor was filed on February 15, 1871; and the same is marked "Complainant's Exhibit Durfee Patent No. 114,277."

Introduction of this exhibit is objected to by defendant's counsel, as incompetent at this stage of the case, and as immaterial, not having been referred to by the defendant herein.

Complainant's counsel states that the same is referred to in the specification of one of the two U. S. patents of Durfee, which have heretofore been offered in evidence by the defendant.)

R. D. Q. 112. Referring to your answer to X Q. 95, wherein you state that you find nothing in the Jones patent referring to the equalizing of the temperature of the metal, will you please state further what, if anything, you find in said patent specification warranting the statement of your direct examination that the
716 temperature of the metal is equalized and the variations in temperature made gradual by the Jones method?

A. In the specification, page 2, line 39, the patentee says: "I thus secure as much as possible uniformity in character of the metal which is fed to and discharged from the tank, and cause the fluctuations in quality of the successive tappings to be very gradual." With regard to the performance of the metal in the converter, its temperature is just as distinctively a part of its character or quality as is its chemical composition; so that I think equalization of temperature is fairly included in the specification, although not specifically referred to.

R. D. Q. 113. Referring to the Whitney practice, about which you were asked in X Q. 102, will you state whether the making of the fluctuations in character or quality of the metal gradual, which you have said is a distinctive feature of the Jones method, would be of any utility as a mode of producing uniformity in metal for casting car wheels?

A. It would not. Any wide variation from a proper character of metal will cause a bad wheel, and it is immaterial whether this change of quality has come about in a short time or in a long time; the character of the wheel depending entirely on the quality of the iron of which it is made. On the other hand, in the Bessemer practice, considerable variation in chemical composition may be allowed, but sudden and abrupt variations are very undesirable. The Whitney practice, it must be observed, is a series of short sepa-

rate operations, and is not continued from day to day as is the direct Bessemer process. The only variation in quality of metal from the cupola worthy of consideration is simply in the small amount of iron first tapped, the cupola being freshly charged each day and the operation started anew. In the direct Bessemer process, the blast furnace runs continuously, but unfortunately does not produce the remarkably uniform quality of iron which
717 can be obtained by carefully testing and assorting the pig metal and remelting the same in the cupola.

R. D. Q. 114. Will you please state what you understood X Q. 108 to mean? I ask this question in view of the suggestion you have just made that you may have failed to make clear your meaning or your understanding of the question.

A. My understanding of the question was that instead of putting in the metal in additions of say 10 tons every 15 minutes, this metal should flow in a continuous stream into the mixer; or, in other words, that 40 or 50 tons of iron requires as long a time to flow into the mixer as if it had been added in the ordinary way. If a large amount should flow quickly, the effect would, of course, be the same as if a number of portions aggregating the same amount should be poured in at once, instead of successively at regular intervals.

JULIAN KENNEDY.

718 PITTSBURG, *April* 20, 1897.

Met pursuant to agreement.
Present, counsel as before.

Testimony of Perry D. Mackey.

PERRY D. MACKEY, a witness produced for complainant in rebuttal, having been duly sworn, deposes and says as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence and occupation?

A. Perry D. Mackey; age, 32 years; residence, Wilkinsburg, Allegheny county, Pennsylvania; occupation, foreman of the converting department of the Edgar Thomson steel works.

Q. 2. How long have you been employed at the Edgar Thomson steel works?

A. Since 1879.

Q. 3. How long have you been foreman in the converting department of the Edgar Thomson steel works?

A. Since September, 1894.

Q. 4. What was your position prior to becoming foreman of the converting department, and how long did you hold such position?

A. Blower, from 1885 until the time I was made foreman.

Q. 5. What are the duties of the blower?

A. To regulate the iron as it comes from the furnace department. The business of a blower is to regulate the iron and bring it uniform. There is a certain amount of scrap to be used for each heat, and we regulate the heat by the previous heat.

Q. 6. Has a blower anything to do with the converter, and if so, what?

A. The blower has full charge of the converter; that is, he regulates the temperature of the converter. Iron must be a cer-
719 tain temperature to do the work to give you a good finished material, and also good work in the converting department.

Q. 7. I want you to describe the operation of the converter, stating where the molten metal is brought from, how it is brought, and what is done with it.

A. The metal is brought in large iron ladles, then it is poured from those into the converter, blast is turned on it, and it is the blower's business then to watch that flame and add the scrap that is needed to bring that iron to the right temperature, the blower always being guided by his previous heat, how to scrap his following heat. Say that he put 1,000 pounds of scrap in a heat and in his judgment that was too little or too much, he would regulate the next heat accordingly, so that at that rate one heat is always relative to the other in our practice.

Q. 8. You have spoken of a flame that the blower observes. What flame do you refer to?

A. When the blast is turned on the converter it causes a burning there of carbon, that is the flame that I referred to as being the blower's guide.

Q. 9. You have spoken of "scrap." What is this scrap?

A. It is usually the refuse of the Bessemer department, steel scrap, rail-end scrap, bloom scrap, or any other kind of scrap would do; it is merely to cool off the iron, bring it to the proper temperature.

Q. 10. Do you put scrap in every heat?

A. No. The iron varying in silicon, silicon is what makes your temperature, and, of course, in low silicon we don't use scrap; high silicon we use a great deal of scrap.

Q. 11. I suppose you refer to the silicon in the furnace or mixer metal that is charged into the converter. Am I right in this?

A. Silicon in the mixer iron is usually very regular, decreasing or increasing very gradually, so that the blower can judge it very readily by his previous heat. On the other hand, the direct
720 iron is very irregular, varying from white iron or low silicon iron to as high as 4 per cent. silicon, making the converting-mill practice very irregular and very unreliable. The variations being so great in iron of the one cast, it is an impossibility for the blower to follow it. In consequence he has chilled heats and very bad finished material. Low silicon iron requires no scrap, while 4 per cent. silicon iron would require from 8,000 to 9,000 pounds of scrap. The variation between the two, the blower regulates according to his previous heat, as I have said before. Had he been using iron requiring from 5,000 to 8,000 pounds of scrap and prepared for his next heat the same amount of scrap, the consequence would be he would have a chilled heat. What I mean by "chilled heat" is a heat that would be a dead loss to the company.

Q. 12. You speak of preparing your scrap. Please explain this fully.

A. The converter is always scrapped ready to receive the iron. We have men who do nothing else but charge the converter with scrap ready to receive the iron. It is the blower's business to tell these men how much scrap to put in.

Q. 13. Then I understand that the scrap is put into the converter first and the furnace or mixer metal is poured on top of the scrap. Is this correct?

A. Yes.

Q. 14. And if the furnace or mixer metal is unexpectedly low in silicon, and you have the amount of scrap in the converter for a metal which you expect to be high in silicon, what is the result?

A. The result is that we would have a "chilled heat."

Q. 15. By "chilled heat" you mean a chilled converter charge?

A. Yes, sir.

Q. 16. Is there any difference between metal that comes direct from the blast furnace and metal that comes from the Jones
721 mixer in regard to being met with surprises in the amount of silicon that is contained in the converter charge? I refer to your own experience.

A. There is a great difference between the two. You pour a low silicon into the mixer, then you pour a higher silicon in, that gives you a more uniform iron; where, on the other hand, you pour five ladles in small amounts direct from the furnace, one of those conversions may chill, the other may be so hot that the blower would be unable to get his temperature regulated properly, and that would also be spoiled by being too hot.

Q. 17. I am not referring to the mixer but to the converter. Have you found any difference in the practical operation of the converter in regard to metal that comes direct from the furnace and metal that comes from the Jones mixer?

A. Yes. Iron that comes from the Jones mixer blows very quickly, and the consequence is very easy on the refractory, not giving us much trouble to keep the converters in repair. The iron that comes direct from the furnace usually blows long and is hard on the refractory and the converter bottoms by wearing them out by the increased length of blows.

Q. 18. I am referring to the operation of what is known as "scrapping." Is there any difference in metal that comes direct from the blast furnaces and metal that comes from the Jones mixer, in regard to sudden changes in the amount of silicon?

A. Yes. The changes are very rapid in the direct iron, where in the mixer they are very gradual.

Q. 19. Is it possible practically to run the converters without producing chilled heats where there are sudden changes in the silicon of the furnace metal, and if not, why not?

A. No, you can't do it. The reasons are the changes are so sudden and varying so greatly that a blower is unable to keep pace
722 with it; the consequence is he will underscrap one heat, spoiling it by being too hot; the other he would overscrap, causing its conversion to chill.

Q. 20. What is the effect on the works of a chilled heat?

A. It causes the stoppage of the mill.

Q. 21. Does that refer only to your department?

A. No, sir. The consequence is the furnace department gets an overproduction of iron on hand which, we being unable to take, skulls and chills in the ladle.

Q. 22. What do you do with the metal when it is chilled?

A. It is poured out on the ground to begin with, taken to the skull-cracker, broken up and remelted again.

Q. 23. Why does the overscrapping cause a chilled heat?

A. In overscrapping, that is, you put more scrap in than you have got temperature or silicon to melt properly.

Q. 24. That is, you put more cold in than you have heat?

A. Yes, sir.

Q. 25. I understand in your testimony that you have been a blower at the Edgar Thomas steel works before and since they used the Jones mixer. Is that correct?

A. Yes, sir.

Q. 27. And prior to the use of the Jones mixer you used the metal direct from the blast furnace. Is this correct?

A. Yes.

The entire deposition of this witness is objected to as not proper rebuttal evidence.

Cross-examination by defendant's counsel:

X Q. 27. What do you do when you find that the metal in the converter is too cold?

A. You don't do anything; it is impossible to do anything.

X Q. 28. Can you not heat it up in some way?

·723 A. No, sir.

X Q. 29. Can you not side-blow it?

A. You can.

X Q. 30. Does not that heat it up?

A. It is a question whether it does or not.

X Q. 31. Well, it has been the custom at the Edgar Thomson steel works to side blow the metal, has it not?

A. Yes, occasionally.

X Q. 32. Why did you side-blow it?

A. To try and get it as hot as you could.

X Q. 33. It is the practice now at the Edgar Thomson works to side-blow the metal, is it not?

A. We blow an occasional heat on the side, but it is not the regular custom to side-blow.

X Q. 34. This side-blowing is accomplished by turning up the converter, so as to let the air forced in partially play on the top of the metal, is it not?

A. The air does, of course, do that. The air plays over part of it and through part of it.

X Q. 35. I believe you do not side-blow your metal in the converter as much now as you did three or four years ago. Is this correct?

A. Yes.

X Q. 36. Why did you change the practice in this regard?

A. Building the mixer did it for us, gave us a more regular uniform iron, we haven't now the occasion to do it.

X Q. 37. You have had the mixer for about ten years, haven't you?

A. No, sir. The mixers were built the latter part of 1888.

X Q. 38. But I understand that three or four years ago it was your custom to side-blow the metal more than you do now?

A. We were running a lower silicon at that time than we do at present.

724 X Q. 39. When you find that your heat in the converter is too high in temperature, what do you do?

A. We add scrap to it.

X Q. 40. That is, you turn down the converter and add scrap to the charge?

A. Yes, sir.

X Q. 41. And that is your custom at the present, I presume?

A. Yes, sir.

X Q. 42. Have you any knowledge of the blast-furnace practice either before or after the introduction of the mixer at Edgar Thomson?

A. No.

X Q. 43. Have you any knowledge of the regularity of the metal obtained from the blast furnace now, as compared with the time before the mixer was put in?

A. No.

X Q. 44. When they used the blast-furnace metal direct at the Edgar Thomson, were you furnished with any analysis or other information as to the characteristics of the metal sent over from the blast-furnace department to the converter department?

A. At first there was, but we abolished it altogether; we couldn't go by it at all in our department; we just used the eye as a guide.

X Q. 45. How long did you run direct metal without being furnished with any analysis or other information as to the characteristics of the metal sent over?

A. Probably four years.

X Q. 46. In using the metal from the mixer, are you furnished with any analysis or information of the metal coming from the converter department?

A. Not before using; we are afterwards.

X Q. 47. How long afterwards?

A. Three or four hours.

X Q. 48. What good does the information do you?

725 A. It is used for references in case you should find anything wrong afterwards in the finished material. It is just to refer back to.

X Q. 49. Then it does not aid you at all in directing the blowing of the metal?

A. None whatever.

X Q. 50. What variations in silicon have you between the consecutive heats in using mixer metal?

A. We only take every other heat and the variation of course is very slight, one may go 1.15 and the other 1.25.

X Q. 51. Is that the maximum variation that you have between consecutive analyses of charges?

A. That is about the largest we have.

X Q. 52. About what is the highest percentage of silicon metal that you blow?

A. About 1.40 silicon.

X Q. 53. About what is the lowest percentage?

A. About 1 per cent.

X Q. 54. You say that stoppage in your own department leads to overproduction of iron in the furnace department, which, as you are not able to take it, causes scull and chills in the ladles. In case of such stoppage in your department, would a reservoir to hold this overproduction in the blast-furnace department have been of use?

Objected to as improper cross-examination.

A. Suppose your reservoir was full, what would we do with iron in the ladles back of that yet?

X Q. 55. You did not answer my question. I will ask the examiner to read it to you again and to request a direct answer.

(The witness' answer to the question shows its utter indefiniteness, for in the first place the question does not state a reservoir of any particular size or capacity; it does not state the kind of reservoir, and until these things are made definite and exact, the
726 witness is perfectly justifiable in declining to give a positive answer to the question. Moreover, the witness has been called to testify as to his practical experience in the conversion of metal, and he is not required to answer any questions outside of facts within his own knowledge, and he is cautioned against giving any mere opinions unless they are based upon such facts and the question is made clear to him.)

A. It is out of my department; I don't know.

X Q. 56. You say that when you used direct metal, stoppage in your department caused an overproduction in the furnace department which as you were unable to take it, sculled and chilled in the ladle. When they put it in the mixer, did you find that it acted as a reservoir and overcame this difficulty?

A. No. I don't think the mixer overcame that, because we always have iron waiting to pour into our converter.

X Q. 57. You mean to say that the mixer did not act as a reservoir to hold the overproduction from the blast furnace department?

A. Yes.

X Q. 58. You refer in your testimony to the metal from the mixer varying gradually in silicon. I presume that it would be better and make your work easier if the metal was uniform in silicon, charge after charge, instead of varying in this way?

A. Yes, sir.

X Q. 59. And if the metal is uniform in this way, scrapping

would be unnecessary, or you would scrap uniform amounts for each charge?

(Objected to as the question is indefinite, it not appearing that absolute uniformity in silicon is referred to, or whether it is only partial.

Defendant's counsel protests at this attempt to instruct the witness, as the matter is perfectly clear in view of the former question which was evidently understood by him.)

727 A. Yes, if the iron is uniform, scrapping would be more uniform.

X Q. 60. This scrapping where there is a variation in the silicon or temperature of the different converter charges, causes like variations in the weights of steel produced in the charges, does it not?

A. Oh, yes.

Redirect examination by complainant's counsel:

R. D. Q. 61. In which did the most chilled heats occur in the experience you have had, with the metal direct from the furnace, or metal from the mixer?

A. They were very frequent from direct iron and very rarely from the mixer.

R. D. Q. 62. In which method was the most metal spoiled by overheating?

A. In the direct process.

R. D. Q. 63. In which method was there the most scrapping?

A. In the direct.

PERRY D. MACKEY.

728 *Testimony of M. J. Dowling.*

M. J. DOWLING, a witness produced on behalf of the complainant in rebuttal, having been duly sworn, testifies as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence and occupation.

A. M. J. Dowling; age, 44; residence, Pittsburg, Pa.; occupation, superintendent of Jones & Laughlin's converting department.

Q. 2. Have you had any experience as a pitman; if so, when and where?

A. Yes, sir; at the Edgar Thomson from March, 1876, until June, 1886.

Q. 3. What are the duties of a pitman?

A. To assist in casting the ingots and handling the ingots to the cars, etc.

Q. 4. Do you know the difference between what is called the "cupola" and the "direct" process in the manufacture of Bessemer steel?

A. Yes, sir.

Q. 5. Which of these methods was employed while you were at the Edgar Thomson steel works?

A. Both the cupola and the direct process.

Q. 6. State the periods of these uses while you were there.

A. The cupola process was used from the time the works were put in operation until, I think, January, 1882, I am not positive about the date. The direct process was used from January 1882, until, I think, some time in 1888.

Q. 7. Did you have practical experience with both these methods at the Edgar Thomson works?

A. Yes, sir.

Q. 8. Please state what, if any, were the difficulties that were experienced with the direct process as compared with the cupola process at the Edgar Thomson works.

729 A. During my experience with the direct process, the difficulties were many more chilled heats and many more skulled ladles, and much more scrap than with cupolas.

Q. 9. To what extent did chilled heats occur with the direct process while you were at the Edgar Thomson works, as compared with chilled heats you experienced in the cupola method at those works?

A. As far as my recollection serves me, I should say the amount of chilled heats with the direct process over the cupola process would be fully 50 per cent. I have seen as many as fourteen consecutive chilled heats with the direct process.

Q. 10. To what extent did skulling of the ladles take place with the direct process?

A. The skulling of ladles at times became a very serious matter, and I have seen the works on the point of having to stop owing to the fact of the ladles being all skulled.

Q. 11. In which was there greater regularity of heat in casting the ingots in the direct or cupola process at the Edgar Thomson works?

(Defendant's counsel here objects to the entire deposition and to any further questions on the same subject as irrelevant and immaterial, the question in controversy in the present case being as between the supposed invention of the Jones patent and the prior art, and not between the direct process and the cupola process. The objection is also taken to the same as not proper rebuttal evidence.)

A. In the direct process.

Q. 12. Do I understand you that the heat in the casting in the molds was more uniform in the direct than in the cupola?

A. No, sir. The cupola process was more uniform than the direct process.

Q. 13. How did the amount of labor required of the pitman with the direct process compare with the cupola process?

730 A. There was not any more labor employed, generally speaking, in one process over the other; that is, there were no more men necessary, but of course at many times the labor was much more severe with the direct process than with the cupola process.

Q. 14. What are ingot butts?

A. Ingot butts are short pieces of ingots made by having too much metal in the converter charge.

Q. 15. In which process did the most ingot butts occur?

A. I should say the direct process.

Q. 16. Why did more butts occur with the direct process than with the cupola process?

A. I should say to that question, that did not come under my department and there were many causes for it; one of the causes would be iron containing high percentages of silicon, the charge would have to be scrapped in the converter to regulate the temperature, and of course there would necessarily be too much metal in the charge, causing the butts.

Q. 17. Is it not a fact that ingot butts are caused either by a surplus or deficiency of metal, so that there is not the exact amount of metal to fill a certain number of ingot molds?

A. Yes, sir.

Q. 18. Which method are they using at Jones & Laughlin's, where you are now employed?

A. They are using the cupola method.

Q. 19. Would you favor the introduction of the direct process at those works, the metal being taken directly from the furnace to the converter?

(Defendant's counsel inquires whether it is for the purpose to make the witness an expert, as the last question would indicate.)

(Question withdrawn.)

731 Cross-examination by defendant's counsel:

X Q. 20. When they used the cupola process at Edgar Thomson works, they only had one charging ladle in use at one time, did they not?

A. I don't understand what you mean by charging ladle.

X Q. 21. I mean the ladle that receives the metal from the cupolas and carries it to the converter.

A. Yes, sir, that is right; only one at a time.

X Q. 22. And they had a number of ladles carrying the metal to the converters when they used the direct process?

A. Yes, sir.

X Q. 23. And these are the ladles which you say would skull up?

A. No, sir; none of my testimony referred to those ladles at all.

X Q. 24. Were not these ladles that I have referred to, carrying the metal from the blast furnaces to the converters, liable to skull up?

A. Yes, sir.

X Q. 25. And that reduced their holding capacity, so that all the ladles would not hold the same amount of metal when filled up to a like distance from the top?

A. Yes, sir.

X Q. 26. Did not this cause the weight of the charges to the converter to vary or be irregular?

A. Yes.

X Q. 27. And this is one of the causes of the production of irregular weights of steel in the converter, leading to the formation of butts or parts of ingots, was it not?

A. Yes, sir.

X Q. 28. When they were using the cupola process, how many cupolas did they run?

A. Just prior to going on the direct process they were using five cupolas for melting iron, to my recollection.

732 X Q. 29. And the iron from these five cupolas all ran into the common charging ladle and was mixed there, and the charge for the converter was drawn from this ladle. Is this correct?

(Objected to as not proper cross-examination, and as indefinite, it not appearing what the words "it was mixed there" refers to.)

A. Yes, sir, that is right.

X Q. 30. Do you remember the capacity of that charging ladle?

A. No, sir, I can't say that I do.

X Q. 31. About how much more than a converter charge would it hold?

A. I don't know.

Redirect examination by complainant's counsel:

R. D. Q. 32. In which is there greater irregularity in the amount of scrap used, in the direct or in the cupola process?

(Objected to as not proper redirect examination.)

A. I should say from my experience that the irregularity would be much greater in the direct process.

R. D. Q. 33. Has the amount of scrap put in the converter anything to do with the amount of metal taken to the ingot mold?

A. Yes, sir.

R. D. Q. 34. Does this in any way affect the formation of butts?

A. Yes, sir.

M. J. DOWLING.

733 *Testimony of Watkin Y. Williams.*

WATKIN Y. WILLIAMS, a witness produced on behalf of the complainant in rebuttal, being duly sworn, says as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence, and occupation.

A. Watkin Y. Williams; age, 53 years; residence, Lorain, Ohio; occupation, I am in charge of the Bessemer converting mill of the Johnson Company.

Q. 2. Have you ever been employed in the Bessemer department of the Edgar Thomson steel works at Braddock, and if so when?

A. Yes, sir; from 1879 until 1888.

Q. 3. In what capacity?

A. As foreman for several years, and as "scrapper," as they call it, for three years.

Q. 4. How was the metal for use in the converters obtained at the Edgar Thomson works during that time?

A. From the cupolas for a portion of the time, and from the furnaces direct.

Q. 5. With or without the use of a mixer?

A. Without.

Q. 6. What was your position at the works during the time when the metal was used direct from the blast furnaces?

A. I was a scrapper.

Q. 7. What were the duties of the scrapper?

A. To regulate the temperature in the vessel.

Q. 8. Relatively speaking, what is the rank of the scrapper; is he in charge of the converter?

A. It was his business to reduce the temperature in the blow to a minimum. The charge of the converter is a different thing.

Q. 9. Who had charge of the working of the converter as influenced by the temperature of the metal?

A. I had.

734 Q. 10. Will you please state whether any difficulties were experienced by you in converting this direct metal, and if so, state generally what they were?

A. The irregularity of temperature.

Q. 11. What trouble did the irregularity of temperature cause?

A. The scrap used would vary in amount, affecting the weights of the charge in the vessel, to make weights of ingots irregular.

Q. 12. Have you ever witnessed the operation of converting metal taken from the Jones mixer at Braddock?

A. Yes.

Q. 13. Will you state whether you noticed any greater regularity in the operation of steel-blowing the mixer metal, than the metal which you formerly used and took direct from the furnaces?

A. Yes, sir.

Q. 14. Have you ever seen the apparatus for mixing blast-furnace metal employed at any other mill than the Edgar Thomson works?

A. Yes.

Q. 15. Where?

A. The Newburg steel works, Newburg, Ohio.

Q. 16. What was this apparatus called in the mill at Newburg?

A. A mixer.

Q. 17. Prior to the use of direct metal at the Edgar Thomson works, where did you get your metal for the converters?

A. From the cupolas.

Q. 18. In supplying cupola metal for the converters, in cases where the ladle was not drained completely in pouring the metal into the converter, will you state whether you ever heard of or ever recognized any advantage in mixing from one charge to the other

by leaving some metal remaining in the ladle, or whether there was any such advantage?

735 A. No.

Q. 19. Did the leaving of such metal remaining in the ladle produce any benefit in the working of the converter, so far as you saw when you used cupola metal?

A. No, sir.

Q. 20. In the use of metal taken directly from the blast furnaces, will you state whether sudden changes in the character of the metal made the scrapper apt to make mistakes in the amount of scrapping, and if so, will you please explain the same.

(Objected to as leading.)

A. Yes. We were expected to keep an even temperature, and with the two extremes of cold iron and hot iron coming so suddenly, it was almost impossible to keep them of an equal temperature.

Q. 21. What effect did such mistakes have upon the steel?

A. The steel that we failed to reduce to a proper temperature would become brittle and unsafe, while the extreme cold heats would make more scrap.

Cross-examination by defendant's counsel:

X Q. 22. Have you been employed in steel works where the mixer was in use, and during its use?

A. No.

X Q. 23. Have you had occasion to handle or deal with metal from the so-called mixer?

A. No.

X Q. 24. Have your duties at any time required you to do anything in connection with metal going into or coming out of the so-called mixer?

A. No.

X Q. 25. Have you had any occasion to test the temperatures or the chemical organization of metal going into, or metal in, or metal coming out of the mixer?

A. No.

736 X Q. 26. Have you had occasion to consult the records of analysis of metal going into or in or coming out of the mixer?

A. No.

X Q. 27. Have you had occasion in a business way to investigate or report upon mixer operations?

A. No.

X Q. 28. Your knowledge, then, of the operation of the so-called mixer is simply that of a casual visitor to the places where they were employed?

A. Yes.

X Q. 29. Up to what date was cupola metal employed at the Edgar Thomson works?

A. I am not positive whether it was 1882 or 1883 they abandoned the cupola practice.

X Q. 30. During the use of cupola metal, it was a frequent practice, was it not, to tap metal from two or more cupolas into one ladle for a converter charge?

A. Yes.

X Q. 31. How long did they continue at the Edgar Thomson works to make steel from molten metal taken from the blast furnace directly to the converters?

A. I think it was until 1887, or the end of 1887.

X Q. 32. Approximately, how much steel was made by that direct process prior to 1887?

A. I can't give any estimate of that. I don't remember what the product of the mill was, and I couldn't give you any idea at all.

X Q. 33. Well, before the mixer was introduced, there were several hundred thousand tons of metal made at Edgar Thomson directly from blast-furnace metal, was there not?

A. Yes, I presume there was.

X Q. 34. In using direct metal previous to the mixer, how did the scrapper regulate the temperature of the converter charge?

A. By adding steel scrap into the converter.

737 X Q. 35. Was this introduction of scrap into the converter also carried on when you used cupola metal?

A. Yes.

X Q. 36. Why did you use scrap with cupola metal?

A. To reduce temperature in the blowing.

X Q. 37. For any other reasons?

A. No.

X Q. 38. Did the metal coming from the cupolas vary in temperature at different times?

A. It varied at different times.

X Q. 39. And there were variations in temperature in the metal coming from different cupolas, as well as in metal coming from the same cupola at different times?

A. That is a complicated question. The temperature from the cupolas at different times would vary.

X Q. 40. In practice the cupolas were usually charged with a mixer of pig iron and steel scrap, were they not?

A. Yes.

X Q. 41. When a cupola in use was working cold or badly it was a common practice to omit the steel scrap and charge with pig iron alone, was it not?

A. Yes, sir.

X Q. 42. Was this done with all the cupolas at one time, or with such only as were giving trouble?

A. With all.

X Q. 43. I think you misunderstand my question—if one cupola was running well and another was running cold or badly, would you omit the steel scrap from all the cupolas?

A. No. I wouldn't omit it from either in that case.

X Q. 44. What would you do?

A. I would increase my fuel.

X Q. 45. When you did omit the steel scrap from one cupola did you omit it from the others that were running properly?

738 A. Yes, sir. Understand that I haven't omitted the steel in one cupola. I have said that if I omitted it in one I would omit it in all; but I have not said that I omitted it in one.

X Q. 46. But there were times when you omitted the steel and ran pig alone in the cupolas to bring them to proper working condition?

A. Yes, sir.

X Q. 47. When previous to the mixer you employed direct blast-furnace metal, did you mix that metal with cupola metal?

A. We did to fill out a heat in order to get a necessary weight for the ingots.

X Q. 48. Explain how, previous to the Jones mixer, you combined the molten blast-furnace metal with the molten cupola metal for use in the converter?

A. By running the ladle under the troughs of the cupola until we got the proper weight of iron in that ladle for the converter charge. The ladle contained iron from the blast furnace when it was taken to the cupola.

W. Y. WILLIAMS.

739 *Testimony of John E. Fry.*

JOHN E. FRY, a witness on the part of the complainant in rebuttal, being duly sworn, deposes in answer to interrogatories by defendant's counsel as follows:

Q. 1. State your name, age, residence and occupation.

A. My name is John E. Fry; age, 59 years; residence, Philadelphia, Pa.; occupation, practical steel-maker, with special reference to Bessemer steel.

Q. 2. What technical training and what experience have you had in and about the manufacture of iron and steel?

A. I was employed for 11 years as superintendent of the foundry of the Cambria Iron Company and for 10 years as the superintendent of their Bessemer steel works. I have been employed as superintendent of other Bessemer steel works for several years, namely, the Vulcan works of the St. Louis Ore and Steel Company; the works of the Springfield Iron Company at Springfield, Illinois; the works of the Wheeling Steel Company at Wheeling, W. Va.; the works of the Hainsworth Steel Company at Pittsburg, Pa.; in all a service of about 28 years as superintendent of works. During all this period I made a careful study of the technique of the Bessemer steel business.

I was officially associated with Alexander L. Holley during my service as superintendent of the steel department of the Cambria works, he being their consulting engineer, and I was very intimately acquainted with him during that period and until his death. I was also officially associated with Wm. R. Jones during his em-

ployment at the Cambria iron works, and was intimately acquainted with him.

Q. 3. Have you seen and do you understand the Jones method of mixing molten metal preparatory to its further treatment in the Bessemer converter?

A. Yes, I have seen and understand the Jones method of mixing crude molten iron preparatory to its conversion.

740 Q. 4. As a skilled steel-maker, will you describe the Jones method and state what its characteristic features are and what it accomplishes?

A. The Jones method is designed to remove that difficulty in Bessemerizing direct metal which is due to its lack of homogeneity in chemical and physical conditions, and to prevent sudden variation in the quality of the metal supplied for conversion.

The method comprehends accumulating and maintaining a relatively large body of molten blast-furnace metal, to which relatively small portions are added from time to time, and from which the converter charges are withdrawn, so that the added portions have a sufficient time to become mixed with the larger body of metal before being withdrawn for conversion. By this operation the variations of chemical and physical character in the added portions are "averaged up," with the result that the portions withdrawn are practically uniform with each other, or vary so gradually in their composition and temperature that the converter man will be able to keep step with the gradual changes in the successive charges for the converter.

Q. 5. What change, if any, in the Bessemer art was effected by the Jones method?

A. Prior to the successful regular use of direct metal for conversion brought about by the Jones invention, the irregular character of different grades of pig iron was compensated by selection of those which, when mixed in proper proportions and melted in the cupola, would result in a suitable metal charge for conversion.

Owing to the vicissitudes of blast-furnace practice the variations in the character of the molten metal obtained at consecutive casts of the furnace are of too wide a range to admit of its successful direct use in the converter when a practically uniform steel product is required.

Prior to Jones' invention metal direct from blast furnaces
741 was used to some extent, but the product was variable and much steel of inferior quality was made which could be sold only at a reduced price.

On the other hand, the large expense incurred in the general practice of remelting pig iron could be avoided by using the direct metal, the costly cupola apparatus and its operation could be dispensed with, and the sensible heat of the metal from the blast furnace utilized in the conversion operation with all the valuable economic results these would imply. The contamination of the metal by sulphur in passing through the cupola would also be avoided. But notwithstanding these great inducements to use the molten metal in the condition in which it came from the blast fur-

nace, the use of pig beds and cupola furnaces continued as the best, and as the generally prevailing practice.

To the practical man, the striking and essential feature of the Jones method is the production of molten metal for the converter, the successive ladles of which will not show sudden changes in chemical composition and sensible temperature. The mixer containing a very large amount of metal, compared to the amount drawn off or added at any one time, the average composition and temperature of the whole mass in the mixer will change very slowly, notwithstanding there may be considerable variations in the chemical composition and temperature of the lots of metal received from the blast furnaces and poured into the mixer. In other words, a gradual variation in the chemical composition and temperature is substituted for the sudden and possibly great changes experienced when using the metal direct from the blast furnace to the converter. In practice the blower or scrapper is governed in determining the temperature of any heat to a considerable extent by the heat phenomena of the preceding conversion, but if the successive ladles of molten metal show abrupt changes in chemical composition and temperature, he is practically at sea and runs the great risk of not scrapping the conversion properly.

742 Captain Jones succeeded in overcoming the difficulties by his invention, and thereby gained the advantages belonging to the use of direct metal. The result is that his invention has been put into extensive public use, and is being rapidly adopted throughout the world. In my opinion, it was the most decided forward step of progress the Bessemer art has taken in an economic direction since its inception.

Q. 6. Then, as I understand you, defective products from a Bessemer converter are caused not so much by mere variations in chemical composition and temperature of the metal charge as by sudden variations therein?

A. In conversion by the Bessemer process, the blower has resources at hand that will enable him to take care of considerable variations in chemical composition and temperature, provided he has sufficient information of them. If the changes are gradual, he can accommodate himself to them very readily. If the change is abrupt, while he may expect the change, he has no knowledge of its degree, until too late to correct any mistakes he may have made in estimating what the change would amount to. To illustrate: If the change is in the direction of colder working metal, he would leave off a certain amount of scrap in his converter, or if too cold he would turn the vessel in such a position as to burn iron to make heat, technically known as side-blowing, and an exceedingly wasteful proces. On the other hand, if the change is in the direction of hot-blowing metal he would increase the amount of scrap added, or blow in steam with the air, or both, as the necessity might indicate. There is very little time to come to a decision. The blower must make up his mind promptly. If he makes a mistake in either direction the steel is liable to be spoiled.

Q. 7. Would the results of the Jones method be secured by a

practice in which the tap-holes of a number of blast fur-
743 naces are connected by spouts to a common reservoir, into which the casts of the furnaces are run, and from which the converter charges are tapped?

A. No. The arrangement which you state contemplates introducing entire casts of one or more blast furnaces into the reservoir at once, instead of, as in the Jones method, introducing the metal in portions added from time to time, and balancing the same by withdrawing portions from time to time for the converters. In the arrangement supposed in your question, the whole cast is run into the reservoir at once, for when the tapping of a blast furnace is started it cannot practically be shut off before the whole contents have run out. Therefore, a very large addition at each cast would be made to the reservoir, and sudden and violent variations and jogs in the heat and composition of the converter charges would be occasioned.

The additions and withdrawals of metal should be so related to the quantity of molten metal in the Jones reservoir that the additions would remain in it a sufficient period of time to insure a proper mixture without being held too long, in which latter case the result would be a considerable loss of sensible heat by radiation and a change in chemical and physical condition of the metal not desirable.

Q. 8. Why cannot the flow of metal from the blast furnace be stopped before the furnace is completely drained?

A. There is no practical method that I know of for shutting off a furnace when only a portion of the cast is being run that is trustworthy, that would leave the tapping hole in proper condition for a continuous operation of the furnace, or that would be practiced by any blast-furnace manager.

Q. 9. Would the results of the Jones method be secured by running the metal from the blast furnaces into the hearth of a reverberatory furnace and there either superheating it or treating it with additions, and then drawing it out for use in the converters?

744 A. No. In the former case the superheating is only another form of cupola practice, in that it adds sensible heat to metal having too little of it for conversion. The Jones method demonstrates in actual continuous practice its independence of added sensible heat beyond the heat inherent to the direct metal itself. Were it intended to "warm up" molten iron poured into a reverberatory furnace, the time required to increase its temperature to an appreciable degree would be a bar to its practicability in the impetuous progressive steps of the Bessemer operations.

In the case of additions made to a body of metal in a reverberatory furnace, such practice would properly belong to foundry and open-hearth methods, but would have no place in Bessemer operations for the purposes contemplated by the Jones method, which, as I understand it, has no use nor time for reverberatory furnace action.

Q. 10. Are you familiar with the practice of running metal from several cupolas into a ladle from which it is charged into the converters? Does such practice secure the results of the Jones

method, even in cases where part of metal is allowed to remain in the ladle after charging the converters?

A. I am quite familiar with cupola-melting practice. From its introduction in Bessemer work until today the mixing of cupola pig iron to secure a proper chemical condition for conversion of the melted product is complete and sufficient before the iron reaches the receiving ladle. This is done by assortment of desirable grades of pig iron and charging them into the cupola so that any one small portion of the melted product is representative of the whole. In other words, were it not for certain purposes, foreign to the chemical or physical composition of the metal and relating entirely to practical details of operation, the metal would better be tapped directly into the converter without intercepting it by the
745 ladle. The ladle receives metal from more than one cupola furnace simply because the cast of one cupola is not large enough to constitute a converter charge. The ladle performs no mixing function in either good or bad practice. Its office is mechanical only. There is relatively little difference between the amount of metal in a converter charge and that which a cupola ladle holds. A newly prepared ladle holds somewhat more than a charge, for the very simple shop reason of ensuring certainty in weighing out the converter charge; because

(*a*.) Occasionally metal will "chill" around the sides of the ladle, and thus reduce its holding capacity before it can be cleaned and newly lined.

(*b*.) More or less slag gathers on top of the metal, which requires to be held so as not to flow over the top.

(*c*.) The small quantities of metal not entirely drained off when pouring, sometimes chill to and befoul the bottom of the ladle and reduce its holding capacity. From these chief causes of fouling, the engineer finds it necessary to give the ladle an original or clean capacity somewhat greater than suffices for a converter charge, but for these reasons only, and not with any view of retaining after pouring a relatively insignificant quantity of metal in any hope that it could favorably influence the large quantity fresh and hot from the cupola.

Q. 11. What have you to say to the statement that at the Cambria iron works after 1871, it was the practice in charging the converters to tap the cupolas into a ladle, and in pouring out the converter charge to leave a quantity of metal in the ladle?

A. During the time I was employed at the Cambria iron works, from 1871 until 1881 inclusive, what was known as the Holley fixed ladle was in use to receive metal from the cupolas. It was what is known as a 10-ton ladle. It would hold about 20,000 pounds when cleanly lined. Converter charges were from 12,000 to 14,000 pounds during that period. During the entire period the conversion
746 capacity was greater than the melting capacity of the cupolas, and it was the regular practice to pour a converter charge as soon as it was melted and in the ladle. There were infrequent occasions, of course, when a greater quantity was in the ladle than was required for a charge, in which case only the converter charge

would be poured, but the general condition of the ladle in practice was such, from its skulled-up condition, that it as often held less than a full converter charge than more. There was no advantage sought from having an excess of metal in the ladle, except that in pouring a converter charge from a full ladle the ladle did not have to be tipped so far over to empty a complete charge, its trough consequently did not go down so flat and the ladle was easier turned back to its upright position. This was not an advantage to the process but a convenience to the workmen. When the ladle was not full enough to hold the converter charge, it was still useful to pour it because it facilitated rapid work in the Bessemer department while the new ladle was being prepared.

Q. 12. Was there any mixing function like that of the Jones method intended or performed in the use of the ladle at the Cambria iron works?

A. No. If there had been any such intention it would have been known to me.

Q. 13. If it were the practice in a Bessemer works to tap several cupolas into a receiving ladle, say 35,000 pounds, and to draw therefrom converter charges of say 15,000 pounds, leaving in the ladle before the next tapping a residual body of metal of 5,000 or more pounds—would such practice give the benefits of the Jones method?

A. Your question assumes as possible a condition in Bessemer works cupola practice which does not exist. There is no mixing to be performed with the cupola metal after it is melted. The cupola metal is uniform; the metal Jones deals with is variable in
747 quality and it is to control the variations that the Jones method is employed, and in the cupola metal there are practically no variations to control.

If, as you assume, 5,000 or more pounds of metal would remain in the ladle, there would be rather a disadvantage than an advantage in such practice in the loss of sensible heat by the exposure of this metal continuously.

Even if you assume falsely that the successive taps from the cupola into this ladle are as variable in composition as the successive taps or casts in a blast furnace, there would not be the same results as to uniformity, because assuming that in the variation of 5,000 or more pounds the average residual quantity would be less than a converter charge, there would necessarily be an addition to this ladle of several times the quantity of metal retained therein, with the manifest irregularity of composition that that would entail. There would be no useful result. But so far as my knowledge goes, and I have been intimately connected with the Bessemer industry in this country from its inception, I have never seen nor heard of any practice of maintaining such a quantity of metal in an intermediate ladle; I do not believe it ever existed as a regular practice.

Q. 14. In what respect is the steel made by the Jones method a purer product than steel made from metal which has been remelted in a cupola furnace?

A. When pig iron for conversion is melted in a cupola, the percentages of the chemical constituents are changed. The content of

sulphur is increased, with the effect of rendering worthless for important products some grades of iron which would be suitable except for the increment of sulphur it takes up from the fuel in the cupola. That is to say, were such iron used by the Jones method it would make a suitable quality of steel; whereas, if cast into pig and remelted in a cupola, it would not be suitable to convert for high-grade product.

748 Specifications for Bessemer pig iron usually contain a clause limiting the sulphur content to an average percentage in the whole lot that will be low enough, after the cupola increment has been comprehended, to leave the iron fit for conversion into steel that will have good malleable qualities in after treatment in the mill and forge, and for which purposes an undue content of sulphur would unfit it. The Jones method not only does not increase the sulphur, but, on the contrary, it diminishes it from the occurrence in the mixer of incidental chemical reactions which favor the reduction of the sulphur content.

Q. 15. Have you seen the mixer in use at the defendant's works at Johnstown, and if so, will you describe its operation?

A. On Monday, March 29, 1897, I saw the metal mixer used at the Cambria iron works. Its principle of construction is similar to the Jones mixer, and its operation is identical with that set forth in Jones' patent.

When I saw it in use it contained a relatively large body of molten metal which had been brought to it from blast furnaces while liquid, and relatively small portions of such metal were added to its contents from time to time, and other portions were poured from it into a charging ladle and taken to the converters for conversion into steel. In these operations, care was taken to maintain in the mixer a relatively large quantity of metal so that the portions added would remain for a sufficient time subject to the mixing effects of the mixer before being withdrawn. This to "average up" the chemical constituents of the metal and make the fluctuations gradual as is done in the Jones method.

Owing to, or in conformity with shop rules, the withdrawals of converter charges of mixed metals were made with approximate regularity of time intervals, and the additions and withdrawals were made as near "time about" as possible. The additions were about one-fourth larger than the withdrawals, say five of the latter to four of the former, so that the additions were balanced by the withdrawals.

749 An oil vapor jet was used for heating the empty mixer preparatory to serving it with metal at the beginning of the week's work, but after a quantity of metal was added that was above the established minimum of one-half full, there was no further need for the vapor jet and it was shut off.

The normal position of the mixer when not in use was upright, and in this position it received the additions of molten blast-furnace metal. In making a withdrawal, the mixer was tipped or rocked forward, and it was returned to its normal condition when the withdrawal had been made. A mark was placed on the outside

of the mixer so as to move relatively to the motion of the mixer in pouring out metal. This was a chalk-mark or white line, and in addition there was a graduated gauge-board. The mark was placed relative to a fixed point, so that about one-half the capacity of the mixer would represent the minimum amount of metal desired to be retained for mixing effects.

Q. 16. Will you state whether at the time when you saw the defendant mixer, any iron was remelted in the cupolas for charging into the converters, and if so, what proportion of the converter metal was taken from the cupolas?

A. Yes, they were remelting in the cupola. They were using about one-third cupola metal and two-thirds mixer metal.

Q. 17. Was the cupola metal taken in the ladle to the converters without entering the mixer?

A. Yes, it was not poured into the mixer.

Q. 18. By what name was the mixing receptacle designated at the defendant's works?

A. It was called "the mixer."

Q. 19. You have spoken in your testimony of having been employed at the Vulcan works of the St. Louis Ore & Steel Company. At what time were you employed there?

A. From the summer of 1881 to the summer of 1883, two years.

750 Q. 20. At this Vulcan works, from what source was the converter metal derived; from the cupola or from a blast furnace?

A. From a cupola plant.

Q. 21. Was it ever the practice of the Vulcan works to use in the converters metal taken directly from the blast furnace?

A. No. Direct metal was never converted there. Nor was any attempt made to do it, nor was any apparatus necessary for that work completed.

Q. 22. The defendant in this case has put in evidence a paper printed in vol. 23 of Engineering, 1877, and written by Alexander Holley, describing the Vulcan works at St. Louis. In this paper it is said:

"No American works is as yet using fluid iron direct from the blast furnace, although the Vulcan plant is arranged and the others may readily be modified to do so."

Was this the same plant as the one at which you were employed, and what have you to say as to the arrangement spoken of by Holley ever having been put into practice?

A. It was the same works. In the construction of the foundation and brick work of the cupola-house, Mr. Holley provided an archway in the latter for the passage of a ladle with direct iron, and a hydraulic lift in the former to lift the direct iron to the cupola floor, all for the purpose of using direct metal, but during the time I was employed there no idea was entertained of using direct metal. Holley's hydraulic lift remained unused in the foundation where it was buried. These works have since been dismantled and direct metal was never used in it.

Q. 23. Have you seen the foundry of A. Whitney & Sons in Philadelphia?

A. I saw it quite recently.

Q. 24. Did you see there a receiving ladle placed in front of the cupolas?

A. Yes.

751 Q. 25. Is your knowledge of foundry practice such as to enable you to know from inspection of that apparatus what were its purpose and effect in the making of car wheels? If so, please state the same.

A. I have stated already my foundry experience, which extended 11 years. I am also versed in the casting of car wheels. The purpose of the ladle was to facilitate the casting operation. In casting car wheels, irons of varying character are carefully mixed for remelting in the cupolas, so that a practically uniform metal is obtained for the entire day's cast. The car-wheel capacity of the Whitney foundry necessitated the use of three cupolas; the pouring operations required that the metal should be conveyed to the casting floors in ladles containing about 600 pounds each. It would not be practicable to tap the metal directly from the cupolas into these ladles. The receiving ladle would be used so that the tapping could be done as fast as the iron melted, and the metal would run into the ladle through troughs and would be poured from this ladle into the casting ladles as fast as they could be presented to receive it. By this means they would be enabled to pour their entire day's work in three or four hours.

Q. 26. It has been stated that the capacity of the ladle was from 12 to 15 tons, accordingly as it was lined. What was its capacity when you saw it?

A. Its utmost capacity was 7 net tons. When last used it had 5½ net tons as shown by the skull on the inside of the ladle. When I saw it the works had been shut down for some time and was in the hands of a receiver.

Q. 27. What have you to say as to there being any substantial similarity between the mode of using this ladle and the Jones method?

A. There is no real similarity. The Jones method handles metal of varying quality and gives out charges of varying quality, but controls the variations and makes them gradual. In the

752 Whitney practice such method would be fatal, for constant quality must be obtained, not only in any given day, but from day to day, and that can only be secured by intelligent mixing before the metal is melted in the cupola. In Jones' method the converter charges can be and often are variable from day to day, but being gradual they are easily controlled. Besides, the Whitney practice uses a cupola furnace; Jones' method makes a cupola unnecessary.

Q. 28. Do you know Mr. Robert W. Hunt?

A. Yes; I am intimately acquainted with Mr. Hunt. I was officially associated with him from 1871 to 1873 inclusive, he then being in charge of the Bessemer department of the Cambria steel

works, and I having charge of the blooming department of the same works. Our employment brought us constantly together for mutual consultation as to the steel product.

Q. 29. You mean the Cambria iron works of the defendant?

A. Yes.

Q. 30. Who was Mr. Hunt's successor in the Bessemer department of the Cambria iron works?

A. On Mr. Hunt's retirement from the management of the Bessemer department in the month of August, 1873, I was his immediate successor.

Q. 31. Will you refer to the testimony of Mr. Hunt, on pages 433–434 of the printed record which I now hand to you, and state whether or not Mr. Hunt correctly describes the practice at the Cambria iron works while he was in charge of the Bessemer plant?

A. I can quite agree with Mr. Hunt in his answer to Q. 10 with reference to the passing of the metal from the cupolas to the converter, particularly where he states "if the blowing was close up to the melting, the metal would be poured as soon as a sufficient amount for a heat was accumulated." In his answer to Q. 11 he seems to be in error in claiming that the Holley intermediate
753 ladle in having a greater capacity than one converter charge was therefore recognized as introducing a mixing feature of value. In common with all other managers of that day, and subsequently, Mr. Hunt did not fail to employ every advantageous means to secure a good final product, and if a mixing feature were recognized as a valuable feature in this ladle, he would not have failed to utilize it in handling every converter charge, which his answer 10 indicates he did not. In Mr. Hunt's answer to Q. 13, he refers to the use of two or three cupolas in those days. For a very considerable part of Mr. Hunt's term of management, there was but one cupola used at a time. When the works were designed and put in operation, their productive capacity, as estimated by Mr. Holley, was sixteen heats of five tons each in twenty-four hours. Three cupolas were provided, each of which had considerably more of a melting capacity than the quantity stated; one to be in operation melting, one to be in complete repair ready for immediate use, and the third to be in process of repair. During all of the time Mr. Hunt was there, and the eleven years I was employed in that department, there was no recognition by Mr. Holley, by Mr. Hunt, by myself, or any other person, of any mixing function performed by the cupola ladle. In the light of the practice, such an assumption would have been absurd.

Q. 32. Will you state whether your acquaintance and association and habits of conference with Mr. Hunt were such during his employment at the Cambria iron works that if he had had any recognition of any advantage arising from a mixing of the metal subsequently tapped into the ladle with that which remained therein, as stated by him in Q. 12, you would have been likely to know of it?

A. From my having had an extended foundry experience prior to being called into the steel department, I was the one whom Mr.

Hunt consulted especially with in regard to the cupola practice. I directed the first charging of his cupola; I worked about
754 them more or less during his term of management, with a view to better their operation, and I would have known of any recognition he had of any valuable feature of the process, and especially in regard to the use of this ladle, which at all times during his management was a source of delay and trouble.

Q. 33. How long did you remain in charge of the Bessemer department of the Cambria iron works after Mr. Hunt left the same?

A. Seven years and eleven months.

Cross-examination by defendant's counsel:

X Q. 34. Have you read the Jones patent on which this suit is brought?

A. I have read only the claims of it, and not the specification.

X Q. 35. Why did you not read the specification of the patent?

A. I did not think there was anything specially instructive to me in the specifications. I was asked as to my knowledge of the claims, and read them to form an opinion of them.

X Q. 36. What led you to think that there was nothing specially instructive to you in the body of the specification?

A. I have read a great many patents and find the specifications are rather dull reading. The claims, however, are more interesting, as I suppose them to embody the views of the inventor in regard to the valuable features of his invention.

X Q. 37. How then did you discover that the Jones method, referred to in your answer 4, "comprehends accumulating and maintaining a relatively large body of molten blast-furnace metal, to which relatively small portions are added from time to time, and from which the converter charges are withdrawn, so that the
755 added portions have a sufficient time to become mixed with the larger body of metal before being withdrawn for conversion"?

A. From a knowledge of its operation obtained from Capt. Jones while examining his mixer at the Edgar Thomson works, and for several weeks' observation of its operation while employed to do so by the Carnegie Steel Company in the year 1890.

X Q. 38. Then your knowledge of the "Jones method" referred to *it* in question and answer 4 and the other parts of your deposition where you describe it, is derived from the sources stated in your last answer and not from a study of the patent itself?

A. Chiefly from those sources, and not at all from a study of the patent itself.

(In view of the witness' answers to cross-questions 34–38, the entire deposition of the witness, so far as it relates to the so-called Jones method, and the bearing of other prior methods thereon, is objected to as irrelevant and immaterial, for the reason that it is not based upon the patent in suit, or any knowledge thereof. What the witness may suppose to be the method of the patent is entirely

immaterial to this case, unless it is based upon a study of the patent.

Complainant's counsel replies that he conceives that the value of the witness' deposition resides principally in the fact that he is not examined in any respect as a literary expert; that his deposition is not composed of quotations from publications, and that he speaks merely of matters of fact and actual technical experience, in which his prior training renders him thoroughly and peculiarly qualified.

Defendant's counsel answers that, as he understands it, the question in controversy is whether the method covered by the Jones patent is valid and infringed. The witness' testimony, to be relevant, must necessarily refer to that method and not to something else outside of it.)

Adjourned to meet April 21, 1897, at 10.30 a. m.

756 PITTSBURGH, *April* 21, 1897.

Met pursuant to adjournment.

Present as before.

Cross-examination of Mr. FRY resumed:

X Q. 39. How did you discover that the Jones method was limited to use with blast-furnace metal?

A. From not ever having seen it use metal other than from blast furnaces, and not recognizing any necessity for its use with metal melted in cupolas.

X Q. 40. Were you not aware that at the Edgar Thomson works since the mixer was installed there, it was the practice at times to introduce molten cupola metal into the mixer?

A. I have no knowledge of any such practice.

X Q. 41. What practical experience have you had as to the use of direct metal in making Bessemer steel?

A. I have not had any—that is to say, I never had charge of a works using molten metal directly from the blast furnace.

X Q. 42. You stated yesterday in answer to Q. 37 that you had had several weeks' observation of the operation of the mixer at the Edgar Thomson works while employed to do so by the Carnegie Company in the year 1890. What was the purpose of your employment at that time?

A. I was employed to investigate the practical operation of the Bessemer works and report my views as to its efficiency.

X Q. 43. Did you make a report in connection with this employment, and if so, to whom did you make it?

A. Yes; I made a report to the superintendent of the works—Charles M. Schwab.

X Q. 44. Was that report in writing?

A. It was.

X Q. 45. When you were employed to investigate the practical operation of the works, what instructions did you receive as to your duties, and from whom did you receive them?

757 A. I received oral instructions from General Superintendent Schwab to carefully observe the practice and indicate, if I could, the causes of irregularity of product which sometimes manifested itself in the operation. That is the substance of the instructions.

X Q. 46. Will you please produce that report that you made, as you stated, to General Superintendent Schwab?

A. I did not retain a copy of the report and have no control of the one I passed Mr. Schwab.

(Defendant's counsel calls for the production of this report, which, as shown by the evidence of the witness, passed into the possession of the complainant company through its superintendent, and asks whether it will be produced.)

X Q. 47. What are the minimum and maximum weights of charges or bodies of metal which can be introduced into the mixer in practicing the Jones method, as you understand it?

A. They would be relative to the quantity retained in the mixer, and therefore no definite figure can be given to represent the weights.

X Q. 48. Considering them as relative to the amount of metal in the mixer, what would be the maximum and minimum weights introduced to be included in the Jones method?

A. As the varying quality of the additions would be a factor, I cannot fix any definite quantity, but they should be, of course, sufficiently less than that retained in the mixer to secure a useful effect. A practical man would have no difficulty in determining these quantities to best conform to his operations.

X Q. 49. Am I to understand from your last answer that you are unable to answer the question because you are not a practical man, as you state in your answer 41 that you have never had experience in using the direct metal?

758 (This and the two preceding questions are objected to as not proper cross-examination.)

A. I do not wish to convey to you that understanding. Given all the data, I could then determine what would be suitable additions to make to secure the benefits of the Jones method.

X Q. 50. I have in my question permitted you to assume any necessary data, and what I want to know is taking any amount of metal in the mixer, as you may please, what would be the maximum and minimum weights to be introduced into it to be included in the Jones method?

(Objected to as not proper cross-examination, and as indefinite, not only in regard to quantity of metal, but in other particulars.)

A. There could be no fixed rule in regard to that. With metal too irregular in succeeding charges to be properly converted, the addition should be as much smaller than the body retained as would bring the quality sufficiently uniform to enable the steel-

maker to readily comprehend the variations of the charges brought to him for conversion.

X Q. 51. Is that the best and fullest answer that you can give to the question?

A. I think my answer answers the question fairly.

X Q. 52. Cannot you give the limits of the relative percentages of the metal in the mixer and the metal to be introduced into it, which would be included in the Jones method?

A. Not in the absence of definite data covering the range of variation of factors of influence.

X Q. 53. Take the ordinary operation of the mixer, would it be within the Jones method, as you understand it, if there were 70 tons in the mixer and 10 tons were added to it?

A. I believe it would.

X Q. 54. Suppose there were 50 tons in the mixer and 10 tons were added to it?

759 A. I believe that would be within the Jones method.

X Q. 55. Suppose there were 50 tons in the mixer and 20 tons were added to it?

A. If there were but little difference in the quality of the metal in the mixer and that of the addition, this relatively large addition could be made with useful effect and would come within the Jones method.

X Q. 56. Suppose there were 30 tons in the mixer and 20 tons were added to it in ordinary practice, would that be included in the Jones method?

A. In the case you suppose there might be such a difference in the quality of the metal of the addition and that in the mixer that no useful result would be reached, and my understanding of the Jones method is that it would cover any addition to a body of molten metal that would secure a useful effect in the converter.

X Q. 57. What do you mean by "useful effect"?

A. The "useful effect" I refer to is the correction of irregularities in the quality of metal for conversion that are too great to be followed by the steel-maker, in such way as to enable him to keep in touch with the changes and provide for them by such means as are at his disposal.

X Q. 58. I understand from your testimony that the factors which govern the question are the metal remaining in the mixer on one hand, and the metal added to the mixer on the other hand; is this correct?

A. They would be factors, but not the only ones.

X Q. 59. What are the other factors which govern the question?

A. The withdrawals would be a factor, and the rate of operation would be a factor.

X Q. 60. The factors which determine whether such mixing of the metals takes place as would give useful results are the two I have named, namely the metal in the mixer and the metal added thereto?

760 A. It is not entirely correct, as it comprehends an immediate useful effect, while I think that time enters into the question as a factor.

X Q. 61. I presume that the different proportions referred to in your question- and answers 53–56, would apply as well if the amounts of metal in both the mixer and the addition thereto were reduced to any proper weight; for example, if the metal in the mixer were 35 tons and 5 tons were added, or the metal in the mixer were 25 tons and 10 tons were added, etc.?

A. All other things being equal, my replies would be the same.

X Q. 62. Assume that the entire cast from a blast furnace was 10 tons and that was added to 75 tons of metal, would it be included in the Jones method?

A. The question assumes a quantity represented in a cast which is not a practical one. I cannot understand from what knowledge I have of blast-furnace operations how it would be possible to make so small a cast as regular practice.

X Q. 63. I did not put on you the responsibility of the size of that cast. Please answer the last question.

(Objected to as not proper cross-examination, the witness having testified in chief as to practical operations, and he is not produced for the purpose of giving evidence as to mere theories and operations which he testifies are impracticable.)

A. From whatever source this metal may be obtained or however obtained, if it was of suitable quality for conversion, the addition of a portion of this size to a body of metal of the size stated would, as I understand it, be within the Jones method.

X Q. 64. Before answering the last question, you read the claims of the Jones patent in suit. Did you intend the answer to cover both claims?

761 A. I read only the second claim. I intended the answer to refer to that claim only.

X Q. 65. Your answer 63 would apply also to entire furnace casts bearing the same relation to the metal in the mixer as found in answers 53–56, would it not?

A. Referring to my answer 56, where 30 tons are in the mixer and 20 tons added, if we assume relative quantities five times greater, as your question indicates we might do, then the addition would be so large proportional to that in the mixer, having in view the different qualities of the two bodies of metal, that there might be no useful effect. This, however, would not be practicable in the light of the present developments of the Bessemer industry.

X Q. 66. You do not seem to have answered the question, and I will ask it again. If an entire blast-furnace cast of 10 tons were added to a mixer containing 50 tons, or such blast-furnace cast of 20 tons added to a mixer containing 50 tons, or if such blast-furnace cast of 5 tons were added to 35 tons, or if a blast-furnace cast of 10 tons were added to 20 tons, the metal being the ordinary Bessemer metal such as usually obtained from blast furnaces; would such mixing be included within the Jones method?

A. In the quantities you assume I believe it would be within the Jones method.

X Q. 67. Take the ordinary metal, supposing the vessel contains

10 tons and you added 10 tons to it; would it be included within the Jones method?

A. In my opinion, no.

X Q. 68. You differ in this regard from complainant's expert Kennedy, who said in his answer 73, "I should think to get good work from the process, as a general rule there should be as much left in the vessel before filling as was added to it at one time." Please think the question further, and consider whether such might not be within the Jones method and state your reasons.

762 A. From a practical view point, I do not recognize a useful effect in mixing two bodies of metal as proposed, unless the smaller body is added to the greater one.

X Q. 69. Why not?

A. In the case of two bodies of metal of widely divergent quality, the useful effect produced would not be such as is necessary to enable the steel-worker to conduct his operations intelligently.

X Q. 70. Supposing the metals were not widely divergent, and that there was but little difference in quality between them, and you poured into the vessel the same weight as that contained in it, would it not be included in the Jones method?

A. In the case you assume, there would be no necessity for the application of the Jones method, which is employed to correct great differences, and has no applicability to metal showing but little differences in the respective portions.

X Q. 71. In answer 4 you refer to "the lack of homogeneity of the metal." What do you mean by that?

A. In my answer 4 I referred to homogeneity in chemical and physical conditions, or a general reference to variability in separate portions of metal direct from blast furnaces.

X Q. 72. Did you mean that there was lack of homogeneity in any particular ladleful of metal, or what did you mean?

A. No, I did not, as I know that any particular ladleful of metal would be practically homogeneous at any instant of time.

X Q. 73. How do you know this?

A. It is a knowledge which comes from experience. The practical man trusts to the analysis of a very small portion of any body of metal he is called upon to treat, and experience proves that he can do so safely.

763 X Q. 74. What you mean is that there is such diffusion of the non-metallic substances in a ladleful of metal that the whole mass is practically homogeneous, is it not?

A. Yes, that would be true of any ordinary ladleful of metal at any instant of time. I refer to "time" in this connection, because in a liquid body of metal there are changes occur-ing which alter the composition, and the percentages of mettalloids or non-metallic substances will be changed.

X Q. 75. And this was recognized before 1887, was it not?

A. Yes.

X Q. 76. There is no tendency of the silicon and sulphur to segregate or form pockets in the crude metal, so long as it remains fluid, is there?

A. There would be segregation, but no aggregation, that is to say sulphur will pass off if iron is kept liquid a sufficient length of time.

X Q. 77. Are the facts stated in your last answer as to the passing off of sulphur true if there is no manganese present, and if the metal is not considerably above the necessary heat to hold it liquid?

A. It is, of course, necessary that the heat of the metal should be somewhat above that necessary to maintain it liquid, but the escape of sulphur from the metal is not entirely dependent upon the presence of manganese, as there are other chemical reactions occurring in liquid iron tending to its escape. Manganese, however, by its oxidation, seems to favor, in the largest degree, this escape of sulphur.

X Q. 78. Did you read in the Jones patent in suit any statement whatever that the method covered was to prevent sudden changes in temperature?

(Objected to as not proper cross-examination.)

A. As stated before, I only read the claims of the patent. There is nothing in the claims directly referring to temperature
764 effect, but they are indirectly referred to, I believe, in the reference to the qualities of the metal. The sensible heat of the metal for conversion is as much a quality as the potential heat of the silicon, and, therefere, would come under the operation of the Jones method.

X Q. 79. Read from the patent claims the words to which you refer?

(Objection continued.)

A. As stated in my preceding answer, there is no direct reference to temperature stated in the claim, but in securing uniformity of the metal in its constituent parts, as stated by the second claim, uniformity of temperature between the metal in the mixer and that added would be an incidental effect, which the inventor could not, of course, claim as any part of the invention, because it would be an unavoidable incident of the method.

X Q. 80. What is the basis of your statement in answer 5 that in converting metal direct from the blast furnaces "much steel of inferior quality was made which could only be sold at a reduced price"?

A. I base my statement upon personal observation of the operations at the Edgar Thomson works, at the time they were using metal direct from the blast furnace, and from trustworthy information from Capt. Jones as to the variability of their product of steel rails.

X Q. 81. Have you any personal knowledge that much steel of an inferior quality was made, or that the steel was sold at a reduced price?

A. Yes. I know that much steel of an inferior quality was made, and I know that inferior steel is always sold, or generally always, at a reduced price. I have made considerable inferior steel myself, and had entirely trustworthy information as to its being sold at a reduced price.

X Q. 82. How variable was the product of steel rails at the Edgar Thomson works when they were using direct metal?

765 A. I do not know the exact percentage of inferior rails made, but was assured by Capt. Jones that it was considerably more than the maximum of 5 per cent., which was considered to be fair practice in that day. I saw the books containing the records of it seven years ago, but disremember the exact figure.

X Q. 83. How do you know that the so-called Jones invention is "being rapidly adopted throughout the world"?

A. I believe that statement is justified by the information I get from the technical press and from trustworthy authorities.

X Q. 84. Have you any personal knowledge on the subject whatever?

A. None of a world-wide character, but only relating to a few in this country, which I believe have been installed since Jones put the method in successful practice.

X Q. 85. You refer in your testimony to variations in the character of molten metal obtained at consecutive casts from the blast furnaces. A similar variation and quite a wide divergence in proportion of metalloids was known to exist in different parts of a single cast of a blast furnace long prior to 1887, was it not?

A. Yes, it was known prior to that date, that individual casts from blast furnaces were not entirely uniform character, but the differences were only in degree; that is to say, if a cast contained a large proportion of sulphur it would all have a large proportion; whereas, two distinct casts from a blast furnace would differ widely, one might be quite sulphurous and another contain practically none; and similarly with the silicon content. I obtained this knowledge in 1871 from chemical analyses made at the works where I was engaged.

X Q. 86. I show you a part of the Jones patent, on page 1, lines 29–34, giving an analysis of a single cast. Is that a fair sample of the variation of the metal in a single cast in silicon and sulphur?

766 A. This table indicates a high silicon content in the first ladle, with a correspondingly low sulphur content and a low silicon content in ladle No. 7, with a correspondingly high content of sulphur. I do not conceive that this would be the result from a furnace working under normal conditions, but rather from a furnace which was changing from a hot to a cold condition while reducing this iron. I would not expect as wide a variation as this under normal conditions of blast-furnace practice of that day. Under abnormal conditions of working, I have had similar experiences myself, but they were infrequent.

X Q. 87. Whatever variation would be present in different parts of a single cast, would also be present in the pigs of metal formed from that cast, if it were cast into pigs, would it not?

A. Practically so, for if the metal from the first ladle had been run into pigs, it would have been practically the same as the metal in the ladle, and so with the others, except that these marked dif-

ferences indicated in the metal in the hearth would be somewhat modified by the operation of pouring into the pig beds.

X Q. 88. How and to what extent would the difference be modified?

A. I have used the term "somewhat" modified because there would be no definite mixture relative to the metal going into any one pig bed. Its temperature and fluidity would have influence to an extent that could only be determined by an analysis of the metal after it is cold.

X Q. 89. I want to know how its chemical constituents would be modified or changed so as to affect the differences in different parts of the cast by the mere act of casting it into pig beds?

A. It is fair to assume in this case in question that there was a fairly gradual change in the chemical composition of the metal in the furnace crucible from high silicon iron in the bottom of
767 the pool to low silicon iron in the top of the pool. In running this iron from the furnace, there would be a more definite separation when running into ladles than when spreading it out in the pig beds, and part of the high silicon iron in the trough would flow with the low silicon iron to the lower pig beds.

X Q. 90. But as a matter of fact, substantially the same variations would exist in different parts of the cast when run into pigs, that existed in different parts of the cast when run into ladles, would it not?

A. For reasons I have stated I would not expect to find quite as much variation in different parts of the cast when poured into pig beds as when drawn off into ladles. In the case of a blast furnace working normally there would be no substantial difference in the metal in ladles or in pig beds, but under such abnormal conditions as indicated here my opinion is that they would differ considerably.

X Q. 91. There would, of course, be substantially the same variations between different casts whether run into pig beds or into ladles, would there not?

A. Yes. A high-silicon cast, whether received in ladles or pig beds, would be a high-silicon cast from the steel-worker's viewpoint, and similarly a cast containing high sulphur.

X Q. 92. Suppose that the pig metal so obtained from different casts, or from a cast which showed considerable variations in silicon, were taken to the cupola plant, and without selection charged into several cupolas, would there not be variation as to the silicon content of the metal produced by such several cupolas, the one from the other?

A. I understand your question to imply that all the iron taken to the cupolas was suitable for the purpose of making steel. In this view two or more cupolas should give a melted product suitable for conversion, each independently or all together. If we assume that all or part of this iron is unfit for use the practice you assume would be very bad indeed.

768 X Q. 93. You have succeeded very well in not answering my question. Please read it over and answer it.

A. I may have misunderstood your question, but I have answered

it fully so far as I understand it, it being indefinite as regards the suitability of the iron for the purpose.

X Q. 94. Suppose that there were different furnace casts of pig iron, varying the one from the other in silicon as much as the ladles referred to on page 1, column 1, of the Jones patent, and that the pig metal cast therefrom was transported to the cupola plant, and without selection charged into several cupolas, would there not be a variation as to the silicon content of the metal produced by such several cupolas, the one from the other? Answer the question without assumption and without criticism as to whether the practice was good, bad or indifferent.

(Objected to as not proper cross-examination, and the witness is informed that he is at perfect liberty to give his answer in the form that he sees fit and to make any qualification or criticism that he may see fit.)

A. In the ordinary method of procedure as indicated by your question, and the metals being in about equal proportions, they would be mixed in the unloading, transporting, charging and melting operations to a degree that the metal from one cupola would be similar to that from another for all practical purposes.

X Q. 95. Do you mean that there would necessarily be such mixing in transporting the pigs and feeding them to the cupolas that there would not be variation as to the silicon content of the metal produced by such several cupolas, the one from the other?

A. Yes, that is what I mean; there will be no practical difference that would materially influence the subsequent treatment of the metal.

769 X Q. 96. Then, in your view, there would be such incidental mixing as would produce metal the same in silicon from all of the different cupolas?

A. Yes, practically so with reference to the subsequent treatment of the metal. Any difference there would be in the metal from different cupolas would not be such a great difference as to unfavorably affect the conversion operations, which is to say that if a converter charge from one cupola would be fit for conversion, successive charges from the same cupola would also be fit, and similarly with the other cupolas.

X Q. 97. You do not answer directly what I ask you. Your answer means now that the charges from the different cupolas would be fit for conversion. Would not the metal from the different cupolas vary the one from the other in content of silicon? Please answer yes or no.

A. You seem to have given my previous answer a different meaning from what was intended. I do not assume that a mixture of the irons indicated would be fit for conversion, or that they would not. I have answered and repeat that for all practical purposes contemplated by the question, one charge for the converter would be as fit as another, and therefore, any possible slight variation in the metal from different cupolas or at different times would not affect the operation.

X Q. 98. Please read Q. 92 again and answer yes or no whether there would be a variation as to the silicon content of the metal produced by the several cupolas, the one from the other.

A. There would be no practical variation.

X Q. 99. If there would be no practical variation, why have you in your super-tendency of Bessemer plants been particular to mix the pig metal "by assortment of desirable grades of pig iron and charging them into the cupola"?

A. For the very important reason that I desired a definite
770 content of metalloids in the mixed metal, which I arrived at by mathematical calculation based on the several analyses, and which definite percentage was necessary to the process. That is to say, referring to silicon, I desired to get sufficient to insure successful conversion operation, and yet not such an excess as would make the metal unfit for good work.

X Q. 100. In making this assortment, I understand you followed the analyses given you of the metal used. Is this correct?

A. Not in all cases. Frequently in pig iron we find physical characteristics which sufficiently indicate its chemical composition for the purpose intended, and in such case experience takes the place of chemical analysis.

X Q. 101. How many analyses did you usually have of each cast of the blast furnace?

A. With reference to iron made by the companies I worked with, I do not remember whether more than one analysis was made or not, but my practice when I furnished the samples of pig iron to the chemist was to give him three, one from the first bed, one from the last bed, and one from the middle bed of pigs. Irons which were not made by the companies which I worked for, but were bought by them, and which I worked, were sampled by car-load lots when sampling was necessary; this with reference to silicon and sulphur chiefly; the determination of the content of phosphorus being less frequent, because its content in the iron can be fairly well controlled by the blast-furnace manager.

X Q. 102. Do you ever charge the metal to the cupolas before you receive the analyses of the metal?

A. With reference to iron made at the works where I was employed, almost invariably I worked it before receiving the analyses for silicon and sulphur. The exceptions were when the physical characteristics of the iron indicated it to be of poor quality.

X Q. 103. Is there any way of storing or accumulating
771 molten crude iron or pig metal from several furnaces, either blast furnaces or cupolas, in a common ladle or receptacle, without the mixing of the metals?

A. I should say not, if the stored portions are liquid.

X Q. 104. Where you have several cupolas together, the metal coming from these different cupolas will vary in temperature, will it not?

A. Yes, there will be some variation at times.

X Q. 105. And if the metal from the several cupolas is run into

a common ladle, the temperature of the metal will be averaged by the diffusion of the heat throughout the mass, will it not?

A. In the case you assume of two cupolas supplying metal of varying temperatures to a common ladle, there would be a tendency to equalization of temperature.

X Q. 106. This was known to you as far back as you have any acquaintance with Bessemer practice, was it not?

A. Yes, my knowledge goes back to foundry experience, say to 1854.

X Q. 107. Was it not a fact in Bessemer practice, as far back as the early seventies, that you would sometimes have one cupola producing iron that was too cold of itself to be blown in the converter, and that this iron was run into the common ladle and there mixed with iron from other cupolas that were hotter and so heated up to the proper temperature for conversion?

A. I do not recall any case in which the iron from a cupola was melted too cold for conversion. At the time you refer to, the early seventies, it was the practice to conduct steel operations with the use of one cupola only, and in those days of inexperience I do not remember that there was ever a converter charge melted too cold for conversion.

X Q. 108. Answer my last question as to any time prior to 1887?

A. During that period I recall no case in which the iron was melted with too little sensible heat for conversion. As long
772 as the iron would flow from a cupola, it contained sensible heat enough to convert. If a cupola chilled up, of course, there was no flow from it.

X Q. 109. Answer the same question, considering the metal flowing from one of the cupolas was not sufficiently high in heat for advantageous blowing, and that this metal was mixed with metal of temperature higher than necessary for advantageous blowing. Have you not had such cases prior to 1887?

A. No. A too high sensible heat in metal for conversion is inconceivable.

X Q. 110. Have you not known in your practice prior to 1887, of metal from one cupola that was too cold to blow without loss by skull in the steel ladle, and which was heated up by hotter metal in the charging ladle?

A. No, not too cold to blow. We do not depend chiefly upon the sensible heat of the metal, so much as upon the potential heat of the metalloids. A metal could be so cold as to barely flow into the converter and still contain enough silicon to make an extremely hot conversion.

Adjourned to meet April 22, 1897, at 10.30 a. m.

PITTSBURG, *April* 22, 1897.

Met pursuant to adjournment.
Present, as before.

Cross-examination of Mr. FRY resumed:

X Q. 111. *It has long been recognized that different cupolas* run at different temperature, and that the same cupola often varies in temperature, has it not?

A. It has.

X Q. 112. Also that some grades of pig metal require higher heat for melting than other grades?

A. Not to any considerable degree.

X Q. 113. Well, it is a fact, is it not?

A. The amount of heat necessary to melt the most refractory
773 character of pig metal, compared with that required to melt pig iron of a character most easily melted, would be so little, relative to the latter, as to make it a quite unimportant factor in the practice of melting pig iron.

X Q. 114. Is not the difference in temperature required to melt different grades of pig iron sufficient to cause the most easily melted pig to melt before the most refractory pig?

A. Theoretically, yes; practically, no.

X Q. 115. Does scrap Bessemer steel melt at a different temperature than pig metal?

A. Yes; their melting points are not coincident.

X Q. 116. Does the size or weight of a body of scrap steel or pig iron affect the rapidity at which it melts?

A. A large body requires more time to be completely melted than a small body, but whether or not a given amount of metal would be melted more quickly from one body than the other I cannot say.

X Q. 117. You state that when you and Capt. R. W. Hunt were both at Cambria, you worked about the cupolas more or less during his term of management with a view to better their operation. What was the difficulty of their operation?

A. There was no difficulty recognized as such at that time with reference to the ability to melt iron properly. It was desirous that they should melt more continuously, instead of having short periods of melting life. It was through my efforts that the cinder notch was applied to cupolas there, which enabled them to be run until their refractory linings were worn out without fear of clogging up with cinder. I had immediate charge of the cupolas upon the first occasion when this cinder notch was used, and operated the cupola all night for Mr. Hunt.

X Q. 118. Where two or more cupolas were arranged to run the metal therein into a common ladle, and the statement was made
that it was found advisable to employ a ladle of so large a
774 capacity, because by so doing a more complete mixture of the different irons was effected than would be the case if a smaller vessel were employed, would this not be a recognition of the mixing of the different irons in the ladle?

A. A statement to such effect, would, I have no doubt, express the opinion of its author.

X Q. 119. Please answer my question.

(The question is objected to as irrelevant, and as improper cross-examination.)

A. I understand your question to refer to a statement made, presumably by another, and not by me. I could assume no responsibility for the accuracy of the statement, and have answered to the best of my ability.

X Q. 120. Please state whether, under the circumstances set forth in X Q. 118, the statement found therein would not be a recognition of the mixing of the different irons in the ladle. Answer yes or no.

A. The question assumes that irons of differing character are brought together into a ladle. Yes, in such cases there certainly would be a mixing of them.

X Q. 121. Where two or more cupolas are arranged to run the metal melted therein into a common ladle, and the advantage of this was stated to be "that it would lead to a more thorough mixing of the metal," would this language not be a recognition of the mixing of the different irons in the ladle?

A. Yes. The language would be a recognition of a mixing of the metal from the two or more sources, but would not be clear as to whether that mixing was desirable or undesirable in its effect.

X Q. 122. Under the circumstances of the last question, suppose the metal was tapped successively into this ladle from the different cupolas and charges were drawn from the ladle without emptying it, and the metal from time to time again tapped into the ladle; would this be a proper description of mixing molten metal by charging successive portions thereof into a mixing receptacle, removing portions only therefrom, and then replenishing the receptacle?

A. No. It would not be comprehensive of the mixing contemplated in the Jones method.

X Q. 123. I made no reference specifically to the Jones method in the question. Please read the question again and answer it?

A. As my answers have heretofore indicated, I recognize no mixing effect, that is, not a useful one in the subsequent treatment or use of the metal. In that view, I believe I have answered your question fully.

X Q. 124. I am sorry you waste time by not answering questions directly, and I must restate the question. Where two or more cupolas are arranged to run the melted metal into a common ladle for the purpose of obtaining a more complete mixture of the different irons, such cupolas were tapped from time to time into the ladle, charges withdrawn therefrom without emptying it, and metal again tapped from time to time from the cupolas into the ladle; would this be properly described as mixing molten iron by charging successive portions thereof into a mixing receptacle, removing portions only therefrom without draining the receptacle, and then replenishing the receptacle? Please answer yes or no.

(Complainant's counsel protests against the implication of the question that the witness has wasted time, or has not answered the question, and submits that the last answer is a full and fair response.)

A. The question does not state whether or not the irons from the several sources are of different quality. It is fair to assume from a practical view-point that the metals are as uniform as ordinarily come from steel-works cupolas. In such case, there would be no mixing with any useful effect, as there would be no change in the quality of the metal in the ladle brought about by such added portions or such withdrawals as are implied.

776 X Q. 125. Suppose that the irons coming from the different cupolas are "of different quality," the one from the other, what would your answer be?

A. In such improbable case, I would say that it might be impossible to so regulate the additions from the different sources as to secure a useful and proper mixture of metal for subsequent treatment in the converter.

X Q. 126. Would any mixing of molten irons take place under the circumstances of X Q. 124, considering that the irons from the different cupolas were different in quality?

A. This question assumes conditions quite outside of those of general Bessemer practice. In my direct answer to X Q. 124 I stated that "there would be no mixing with any useful effect." To go further than that in my reply would, in my opinion, be speculative, which I wish to avoid and confine myself to matters of practical facts.

X Q. 127. Are the Jones method and its advantages applicable for pigs for converters or puddling furnaces?

A. I do not understand your question, so far as it recites "pigs for converters;" will you kindly make it clear to me?

X Q. 128. Is the Jones method inclusive of the casting of the metals in the mixing vessel into pigs for use in converters, puddling furnaces, or for other uses to which pig iron can be put in the art?

A. Practically speaking, I see no advantage to arrive from passing crude blast-furnace metal through a mixer to be cast into pigs which must be remelted in cupolas for treatment in the converter.

(Defendant's counsel inquires when the report called for after X Q. 46 shall be produced.)

X Q. 129. What knowledge have you as to the average daily production of blast furnaces from 1870 to 1875?

777 A. A knowledge which would come from the use of metal from several furnaces during the greater part of that time?

X Q. 130. What was the average daily production of blast furnaces from 1870 to 1875?

A. The product was relative to the size of the furnace and the management of it, those being the principal factors. I cannot give definite figures. What I mean by this is that a furnace of a given

size would vary in its average product according to the vigor of its management. This variation, I am safe to say, would be as much as 100 per cent.

X Q. 131. What was the lowest production and what was the highest production per day during that period that you know of? State as near as you recollect.

A. My recollection of the furnaces of that period with reference to their average size was that about seventy tons per day would be considered a fair production for a furnace of the time, and the production, under the same management, would not vary much from this from day to day.

X Q. 132. Do you remember the average daily production of the four old furnaces at the Cambria works from 1870 to 1875?

A. I do not. It was very variable.

X Q. 133. In answering Q. 7, did you consider it as referring to the present day with blast-furnace production as now obtained?

A. No.

X Q. 134. About what period did you intend the answer to refer to?

A. About 1888.

X Q. 135. What average daily furnace capacity had you in mind in answering the question?

A. A capacity of 300 tons or more per day.

X Q. 136. Say in 1870 to 1875, was the ordinary blast-furnace tap-hole larger or smaller than the ordinary stream delivered from a charging ladle?

778 A. A normal tap-hole of a blast furnace would deliver a stream that would be probably smaller than that from a charging ladle, but then, as now, there was no positive control of the size of the tapping hole of a blast furnace, from the fact that it might close up somewhat or it might cut out incident to the character of the metal coming from the furnace.

X Q. 137. Then the stream of metal normally delivered from the blast furnace would be smaller than the stream of metal delivered from a charging ladle?

A. By "charging ladle" I understand you to mean the ladle which carries the charge to the converter. My answer is yes.

X Q. 138. If you have a group of four blast furnaces, each producing from 8 to 12 tons at a cast, and introduce into a common receiving vessel the entire cast from these furnaces, not all at one time, but as the different furnaces are ready to be tapped in the ordinary way of operating them, the metal from these four furnaces being different in quality, and the metal so introduced when tapping a furnace mixing with that in the vessel, and you withdraw from that vessel converter charges when the same are needed, and tap into the vessel blast-furnace charges when ready; would you practice the Jones method?

A. In the practice you describe, definite quantities are poured into a receiving vessel of indefinite size; therefore, I cannot determine whether or not the Jones method would be thus practiced.

X Q. 139. Suppose you had a receiving vessel holding 60 or more

tons, and followed the practice stated in my last question, would you practice the Jones method?

A. Your question is still indefinite to me, in that the method by which "you withdraw from that vessel converter charges," is not sufficiently clear to me to determine whether or not it were practicable.

779 X Q. 140. I mean withdraw a converter charge of suitable weight in any suitable way.

A. There is more than one way of withdrawing charges from such a receptacle that would be a suitable way, so far as the withdrawal is concerned, but I do not have sufficient mechanical knowledge to conceive of but one way that would be practicable, and that is by pouring from a receptacle, as from a ladle.

X Q. 141. Please answer my question 138, considering the receiving vessel to hold 60 tons, and the metal to be withdrawn from it any suitable way.

A. In the case you suppose, with the size of additions as you assume, and the body of metal retained of the size you assume, and assuming additionally that the withdrawals were successively made,—under these conditions I believe the Jones method would be performed.

X Q. 142. When you visited Johnstown on March 29, 1897, and went into the converter department of the defendant's works, whom did you talk with when you were there?

A. Principally with its general superintendent, Mr. F. G. Parker, who was the only one I talked to with whom I had any acquaintance. Other workmen spoke to me, calling my attention to the fact that they had worked for me when I was superintendent there, whose names I do not know.

X Q. 143. How long were you in the works?

A. A couple of hours in the morning, probably an hour and a half in the afternoon.

X Q. 144. In what part of the converter works were you the greater portion of your time?

A. I was a very short time in the office of the works, a short time in the regulator or pulpit where the steel is blown, and was invited by the superintendent to the mixer floor.

X Q. 145. Did you see the oil vapor jet used for heating the mixer shut off?

A. I saw it in operation, it was explained to me by the superintendent, and I saw it shut off. The explanation of the oil
780 vapor jet was made in answer to my inquiry whether the steam used would not have a cooling effect. He explained the jet was induced by an air blast.

X Q. 146. Was not the only time you saw the oil vapor jet shut off when they were pouring the converter charge from the reservoir?

A. No. The shutting off was not incident to the pouring that I could observe.

X Q. 147. How many oil jets were there on the mixer that you saw?

A. I recall but one.

X Q. 148. Where was the burner located that you saw for feeding the oil vapor jets to the reservoir?

A. Adjacent to the pouring orifice, through which the metal passed from the mixer to the converter ladle, so that its flame would pass into the mixer through that orifice.

X Q. 149. Then you did not see that this reservoir had three oil vapor jets?

A. I did not.

X Q. 150. You referred in your Q. 6 to side-blowing. For what purpose is that employed?

A. In my answer to that question I have indicated the purpose to be that when a converter charge would not blow hot enough, this means was employed to give additional heat.

X Q. 151. In what way did it act to give additional heat?

A. To answer that question fully, would require a technical description of prolixity. In general, the operation of side-blowing causes the combustion of iron, the resulting heat of which is retained by the bath under treatment.

X Q. 152. In your answer 9, you refer to "the impetuous progressive steps of the Bessemer operation." What do you mean by this?

A. It has general reference to the fact that in any intermediate department of a Bessemer steel works, there is a demand
781 from the department beyond it for its product and a pressure brought behind it to conduct its operation with the utmost dispatch.

X Q. 153. Does this expression refer to the Bessemer operations of the present time?

A. Not solely. Ever since about 1871, when the Bessemer practice may be considered as having been first established on a successful commercial basis, this impetuosity in this line of manufacture has been strongly manifest, wherever it has been practiced in this country.

X Q. 154. About how many heats per day did you turn out in the Bessemer works of the Cambria Company in 1871 to 1875?

A. The number was variable from year to year, increasing rapidly toward the end of the period you name. I recall that for the first three years it did not more than approximate the number estimated by Mr. Holley, its designer, as being its possible productive capacity. That amount has been stated before by me, his estimate being 16 heats of 5 tons each per 24 hours, or about 25,000 tons per year.

X Q. 155. The records of the Cambria Iron Company show the output in tonnage of Bessemer steel by those works for the fiscal years to be as follows:

1872–1873	30,567
1874	30,864
1875	53,527
1876	63,915
1877	75,172
1878	85,289
1879	93,662
1880	120,208

Is this according to your recollection of the output of those words?

(The question is objected to, because it contains a statement which has not been made the subject of proof, and the question is therefore irrelevant and immaterial.)

782 A. To the best of my recollection these figures represent the quantities made in the respective years.

X Q. 156. To what extent was the cupola plant of the Cambria Company increased while you were in charge of the converter department?

A. There were numerous changes in both plant and practice, leading toward the annually increased production noted in the foregoing figures. Three cupolas were installed at the beginning, one only being in use at a time. Later, when converting practice improved, two cupolas were used at a time. Then, a fourth cupola was added, so that even three might be used at a time; and finally, the three original cupolas were replaced by four of greater capacity. During this entire period of the evolution of the business, there was no change in the number of the converters or in their general size.

X Q. 157. You referred in your testimony to the use of a reverberatory furnace. Would the method of the Jones patent be practiced if different ladlesfull of blast-furnace metal, ununiform in silicon, etc., were run successively into a large reverberatory furnace, say holding 60 tons of metal, and there kept hot, and if converter charges were drawn from the same and fresh ladlesfull of blast-furnace metals were fed thereto from time to time?

A. Decidedly no, as such practice would introduce an incalculable error in the estimation of the character of the iron to be withdrawn for conversion, from the fact that there would be a change produced in the character of the metal by the reverberatory action of the furnace, the measure of which could not be intelligently estimated.

X Q. 158. Assume that the blast-furnace metal was not superheated in the reverberatory furnace, but was there introduced and mixed with other molten metal and simply kept hot; would that be within the Jones method?

A. If it were kept hot by heat introduced other than that
783 inherent in the metal itself, there would then be the changes in chemical character of the metal stated in my former answer, and as long as these changes occur in an indefinite degree, there would be no intelligent application of the Jones method.

Adjourned to meet April 23, 1897, at 10.30 a. m.

PITTSBURG, *April* 23, 1897.

Met pursuant to adjournment.
Present, as before.

Cross examination of Mr. FRY resumed:

X Q. 159. In working the Jones method, as you understand it, the first step is to deliver successive charges of blast-furnace metal into the mixer until it is filled or practically so; is it not?

A. If you refer to the method as practiced by the inventor himself, with which I am familiar, it was.

X Q. 160. And when this mixer vessel was once filled with these charges of blast-furnace metal, you then had a body of mixed or average metal, all of which was suitable for use in the converter, was it not?

A. Under normal working conditions of blast furnaces, that would be so.

X Q. 161. Then if you should draw out of the mixer this metal with which it was first filled, in successive converter charges, it would all produce under normal conditions good steel, would it not?

A. Under normal conditions, as assumed, it would.

X Q. 162. As a matter of fact, is it not the practice at Edgar Thomson at the end of the week's operations, to draw out the metal from the mixer and take it to the converters, without refilling or adding blast-furnace metal to the mixer?

A. Yes, that is the only practicable thing to do at the end of a week's run, in view of the intervention of a Sabbath, when no work would be contemplated.

784 X Q. 163. The practice named in the previous question of emptying the mixer also prevails at the Cambria, does it not?

A. I cannot say, as I have not observed the practice there with the mixer at the end of a week's run.

X Q. 164. After the mixer is last filled, and while it is being emptied, the quality of the metal delivered from it is practically uniform and unchanging, is it not?

A. No. It would be changing in its quality constantly, and the total change in it from first to last would be relative to the amount in the mixer and the rapidity of converting operations.

X Q. 165. State whether the changes occurring during the final emptying of the mixer are material or such as to prevent the practical working?

A. They would not prevent the practical working, because the effects of these changes would be understood and provision made to meet them. In other words, we would expect the consecutive charges, from first to last, to blow regularly colder, all other things being equal.

X Q. 166. Have you made or seen the analyses or the temperature tests of the successive converter charges while the mixer was being emptied?

A. I have no knowledge of the changes which would occur in

your specific cases relating solely to the mixer charges, but in my business operations I have had chemical analyses made of portions taken from a given body of metal at different times, and noted the variation in the qualities which would affect conversion temperature. It is safe to say similar variation will occur in similar bodies of liquid metal under the operation of the natural laws having influence.

X Q. 167. But you had no such actual experience with mixers or mixer metal?

A. Not relative to analyses of the charge withdrawn, but
785 have noted the effects on the conversion temperature of the loss of heat energy late charges would have over earlier charges from this body.

X Q. 168. Then the Jones mixer, as you saw it used at Edgar Thomson, did not give entirely uniform results?

A. Not at all, nor did the inventor, as I understood him, comprehend such, but on the contrary, he recognized the practical impossibility of rendering uniform a continuous supply of metal, and desired only to reduce the abrupt changes of the several portions added to the gradual changes of the portions withdrawn, and this is what he worked out from his invention in a thoroughly practical way.

(Objected to as incompetent and voluntary.)

X Q. 169. Have you read the Jones patent in suit up to this time, or heard it read?

A. I have read only its two claims, and one or two paragraphs to which my attention was called by the defendant's counsel. I have no further knowledge of it.

X Q. 170. When and where were you present during the final emptying of a Jones mixer? I mean the withdrawal of the metal last filled into it to the converters.

A. At the Edgar Thomson works during my short engagement there, in 1890, probably from the latter part of February to some time in April. That is as near as I can recollect now.

X Q. 171. How long did it take to empty the mixer, and were you present during the entire time?

A. My recollection is not clear as to the time, nor was I present all the time, as my duties called me to the converters part of that time.

X Q. 172. Assume that a vessel is filled with successive charges of blast-furnace metal to secure a suitable mixture or average for conversion, and that this metal was drawn out in converter charges, without refilling the vessel in the meantime. Would this come within the Jones method as you understand it?

786 A. No. Not as I understand the Jones method, which relates — only to continuous operations, but also to operations conducted at a given rate per day or week.

X Q. 173. According to your understanding of the Jones method, its purposes and advantages, would similar advantages be obtained if the metal from the mixing vessel were cast into pigs for use in

converters or puddling furnaces, or for other uses to which pig iron is commonly put in the art?

A. Your question is not clear, in that I do not understand to what "similar advantages" are referred to.

X Q. 174. I mean advantages similar to those which you have stated in your testimony as attending or following the use of the Jones method.

A. My answer to your X Q. 128 would also apply to that question.

X Q. 175. Assume that entire blast-furnace taps are delivered into a large vessel, and that converter charges are drawn from this mixed mass of furnace metal, would that be within the Jones method, as you understand it?

A. Not as I understand it, as it comprehends but a single operation.

X Q. 176. What do you mean by its involving only a single operation?

A. Because there is no indication in your X Q. 175 that the performances you state would be continuous,—that is to say, that the body of metal would be replenished from time to time and withdrawals made from time to time, practically continuously, as in the Jones method as I understand it.

X Q. 177. Is the failure to replenish from time to time the only reason why the practice stated in X Q. 175 fails to come within the Jones method?

A. No, not the only reason, as the question in discussion deals with a single specific mass of metal, while the Jones method refers to a continuous operation.

787 X Q. 178. In what particular, other than the failure to replenish, does the method stated in X Q. 175 differ from the Jones method?

A. In my answer to your X Q. 176 I have given my understanding of the Jones method, and taking that as the basis of this reply, the case assumed by your X Q. 175 does not require that this body of metal should be added to from time to time and withdrawals made from time to time, practically continuously, and therein I note the difference.

X Q. 179. If entire blast-furnace taps are delivered into a large vessel and converter charges drawn from this mixed mass of metal, what other steps are required to bring the operation within the Jones method?

A. There should be such a relation of the additions to the withdrawals from this mass as would modify the irregularities of the additions, and the operation must be conducted at a rate that would make it successful in practice. This latter because I can conceive the operation your question states to be performed so irregularly as to time, or so slowly, as to defeat all the advantages gained, if any there are gained, by the use of such an apparatus.

X Q. 180. Do you understand that in the Jones method the additions and subtractions of metal must take place alternately?

A. They are practically so as the inventor himself practiced the

method, but I see no reason that they should be accurately alternated.

X Q. 181. Assume that the additions of metal to and the subtraction of metal from the mixer vary so widely in relation to each other that the volume of mixer metal increases and diminishes 50 per cent., would this come within the Jones method?

A. I cannot understand your question as to whether the variation refers to the size of the additions and subtractions, or of the irregularity of their occurrence. Kindly make this plain to me?

788 X Q. 182. You may answer the question on each hypothesis separately?

A. My opinion is that so long as the effect of the mixer operation changes portions of metal which are too irregular for conversion treatment to metal that can be intelligently treated in the converter, I believe the Jones method would be in operation.

X Q. 183. Am I correct in understanding you to mean in your testimony that the suitable mixing of blast-furnace metal in a vessel, and the withdrawing of this metal in converter charges without replenishing the vessel, would fall outside of the Jones method, but that if the same steps were followed, and in addition the vessel replenished with blast-furnace metal from time to time, this additional act of replenishing would bring the operation within the Jones method, as you understand it?

A. The single operation of your first premise would, as I have already answered, fall outside of the Jones method, but your second premise omits the important factor that the additions must be too irregular for conversion, and the withdrawals sufficiently regular for conversion, to bring it within the Jones method, in my opinion.

X Q. 184. Am I to understand you as meaning that if the additions of blast-furnace metal to the mixer are of a quality suitable for conversion, and not "too irregular for conversion," that it would fall outside of the Jones method?

A. In the case you assume, there would be no need whatever for the application of the Jones method that I can see.

X Q. 185. In practice, do the Edgar Thomson people exclude from the mixer taps of blast-furnace metal when they are suitable for direct conversion?

A. Certainly not; for having provided their system, the metal moves more readily through the mixer than it could be

789 moved direct with the mixer system in operation, and assorting out such suitable charges would be a complication of the operation.

X Q. 186. But the Edgar Thomson people do assort out and exclude from the mixer taps of blast-furnace metal which are exceedingly bad, do they not?

A. I do not recall such practice during my observation there. Such charges, if received in the ladle, would, I have no doubt, go into the mixers, as I have seen dead-white iron poured in on several occasions, and this was about as bad a quality as a Bessemer man can imagine.

X Q. 187. Omitting any inferences and confining yourself to facts

within your knowledge, do you know, as a matter of fact, whether at Edgar Thomson they exclude bad furnace metal from the mixer and cast it into pigs which are subsequently remelted?

A. I have no personal knowledge of that occurrence.

X Q. 188. It is in evidence in this case that the statement in my last question is true. Have you any reason for denying it or believing it untrue?

A. No reason at all; but, on the contrary, believe that such would be the practice at such times as several furnaces might be making very bad iron at one time.

X Q. 189. Then, as you understand it, the mixer is not in practice a corrective for the deficiency in all the metals from the blast furnaces, and does not permit all the blast-furnace metal to be passed through the mixer to the converter?

A. Does this refer to the Edgar Thomson blast furnaces?

X Q. 190. Each and all of the works the operation of which are within your personal knowledge?

A. No. Not of such deficiencies as are likely to result in blast-furnace practice, although I feel safe in saying that in normal working condition of several blast furnaces, practically all the metal would be fit for the mixer in the light of today's development of the blast-furnace practice.

790 X Q. 191. Blast furnaces of the present day give better results and more regular metal, than those a few years ago, do they not, when intelligently handled?

A. The reference to today's practice in my former reply, was more particularly to that time when I was investigating the practice at the Edgar Thomson works, say 1890. The practice there at that time seemed to me to be as good as ever could be expected. Yes, it may be better now.

X Q. 192. Is it not a fact, that good furnace practice of the present day gives better and more uniform results as to the percentage of sulphur and silicon, than were obtained at the Edgar Thomson in 1890?

A. Better economic results, but I cannot imagine blast furnaces doing better work as a regular thing, than the Edgar Thomson furnaces were doing at that time.

X Q. 193. What was the usual or average variation at Edgar Thomson in 1890 in the silicon content of the metal?

A. I cannot recall the figures I saw on the records, as I paid little attention to them at the time, because I based my judgment as to the silicon content upon the physical characteristic of the furnace samples and its blowing quality in the converter.

X Q. 194. Am I to understand you as testifying that the Edgar Thomson furnaces at the present day do not give a more uniform or better average metal than they did in 1890?

A. I cannot testify as to the qualitative results attained there today. I do not know how the furnaces are working at the present time.

X Q. 195. So far as the chemical organization of the metal in the mixer is concerned, what difference does it make whether the entire

cast of a blast furnace is introduced into the mixer continuously by a runner or otherwise, or whether the same metal is delivered from the blast furnace to the mixer by rapidly succeeding ladles?

791 A. From a practical point of view, I would assume that the cast from the furnace would run into the mixer through the troughs more quickly than it possibly could be introduced by a train of ladles. The body of metal in the mixer therefore would more nearly assume the character of the metal run in by the trough than it would from the metal from ladles brought singly to it, with the interval of time between them comprehended in their handling.

(Answer is objected to by defendant's counsel as irresponsive and evasive, and the attention of the court is directed to the fact.)

X Q. 196. Assuming first, that a blast-furnace cast is conducted to the mixer by a spout or equivalent continuous delivery; and, second, that the same metal from the blast furnace is delivered to the receiver by rapidly succeeding ladles, what difference would there be in the two cases between the silicon content of the mixer metal?

A. If you mean that the time required to introduce the metal in the different ways would be the same, and if it would be practicable to introduce it by a spout without interrupting the withdrawals for conversion, I then believe there would be practically no difference in the silicon content of the body of metal in the mixer.

X Q. 197. Does the amount of silicon in the blast-furnace metal increase or decrease appreciably during the transfer of the molten metal to the mixer?

A. It would decrease, but not in a sufficient degree to change its general silicious character.

X Q. 198. To what extent does the element of time effect the increase or decrease of silicon during the transfer of molten blast-furnace metal to the mixer?

A. The longer time it would be on the way, the greater would be the decrease, which is to say that if the metal could be held liquid in the ladle for an indefinite time, the silicon would finally be practically all reduced.

792 X Q. 199. But in practice there is not and cannot be, under ordinary methods, any material elimination of silicon during the transfer of furnace metal to the mixers unless some outside influence is brought to bear?

A. So far as silicon alone is concerned, and as far as my observation has gone, there would be little loss in the transportation of metal, except in case of unusual delay.

X Q. 200. Am I correct in understanding that the different ladles from a single blast-furnace cast will differ widely as to the percentage of silicon and sulphur?

A. I believe you are, if that knowledge is based upon presumably trustworthy information we get in the literature of the subject.

X Q. 201. As a practical man, do you or do you not know that

successive ladles from the same blast-furnace cast vary materially as to the amount of silicon and sulphur contained in them?

A. Yes, materially, though perhaps not widely. I base this statement upon my knowledge of the variations found in different pig beds from the same cast of a blast furnace, as indicated by the physical characteristics of the pig.

X Q. 202. Now if you take these successive ladles of blast-furnace metal, differing as to the percentage of silicon and sulphur, and empty their contents into a single vessel, you would then have a mixed or averaged metal containing of silicon and sulphur the average of all the metals from the ladles, would you not?

A. Yes, practically so.

X Q. 203. Now if, instead of dividing the blast-furnace cast into small bodies by the ladles, and then reuniting them, you should run that entire blast-furnace cast at once into the large vessel, the metal in this vessel would contain practically the same sulphur and silicon as in the other case, would it not?

A. Practically the same.

793 X Q. 204. Then by running the entire blast-furnace cast into one vessel, you obtain an averaging of the silicon and sulphur which would not be found in the separate ladles from the blast furnace?

A. If you mean by an "averaging" that the mass of metal would be likely to have a content of silicon and sulphur different from that in the ladles, or in any one of the ladles, then I quite agree with your proposition. There would be an "averaging up" of the elements referred to.

X Q. 205. And if into the vessel containing the entire furnace charge, an additional furnace cast or casts should be added, there would be a still further averaging up of the silicon and sulphur?

A. Yes.

X Q. 206. What is the highest percentage of silicon you have known to be practically blown in Bessemer process?

A. About 3 per cent. of silicon in a 6-ton converter, as nearly as I can remember. This would be considered a fairly high silicon for a charge of 6-ton weight; an extremely high silicon for a 12-ton charge, and a moderate silicon content for a one-ton converter.

X Q. 207. You have referred to the Whitney car-wheel works. Did you ever visit those works when in operation?

A. I was in them once, many years ago, for a short time.

X Q. 208. Were they then tapping several cupolas into a large ladle, and pouring out small portions about large enough for car wheels?

A. At the time referred to I visited the foundry in the morning, and casting operations were not in progress. I have not ever seen the operation of casting going on in the Whitney foundry.

X Q. 209. When you were in the Whitney foundry some
794 years ago, you saw, did you not, several cupolas, a large tilting receiving ladle, and means for delivering the molten metal from the several cupolas into the one ladle?

A. At the time referred to I gave no attention whatever to the

melting and casting appliances, being interested only in seeing the molders at their work making car-wheel molds.

X Q. 210. Then you have never seen the melting, accumulating or casting apparatus of the Whitney works in operation?

A. Not that of the Whitney works.

X Q. 211. And you have no personal knowledge as to the source or chemical composition of the irons charged into the cupolas at the Whitney works?

A. No; no personal knowledge.

X Q. 212. In foundry practice, is it not common to repeatedly tap and stop the cupola while it contains molten metal?

A. It is more common to tap than to stop in a cupola containing metal, as the general practice in foundry, as practiced by me, was to withdraw practically all the liquid iron the cupola contained at each tap, or, in other words, to tap out as soon as the required amount of iron was ready, and draw it all off, except on rare occasions, when we would stop it with some little liquid metal remaining.

X Q. 213. Do you not know that it is a common practice in foundries or elsewhere, to stop-in the molten metal in cupolas?

A. Not to stop-in with any appreciable quantity remaining. There might be a few inches in depth remaining in the cupola hearth, but a very few inches in depth made the operation of stopping-in hazardous and uncertain, as I know by personal practice.

X Q. 214. In answer 13 you say that the practice of tapping from several cupolas into a receiving ladle of 35,000 pounds, etc.,
795 "does not exist in Bessemer works." What authority have you for saying that this practice does not or did not exist prior to 1887 in any American works?

A. The question refers to a receiving ladle of 35,000-pounds capacity, used for converter charges of about 15,000 pounds. I have seen but one works which this description will fit, the works of the Pennsylvania Steel Company, of Steelton, Pennsylvania, where I had opportunity to observe the practice on two occasions of a day each. The practice I refer to is understood to mean that it was the general practice to tap 35,000 pounds into the ladle, and then pour from it the converter charge of 15,000 pounds. The practice I saw comprehended no such rule.

X Q. 215. Referring to your answer 13 again, did you mean to deny the existence of the practice named, or simply to say that it was not known to you?

A. My answer 13 refers to the practice I saw at those works of the Pennsylvania Steel Company, and I know of no other works treating similar converter charges which has a ladle of the capacity stated.

X Q. 216. Can you deny that the Cambria works used in 1889 had a ladle of 35,000-pounds capacity?

A. I can neither deny nor affirm, as I know nothing of the ladle used at those works at the date named.

X Q. 217. Is it not a fact that the Cambria works in 1877 used a

charging ladle of 28,000-pounds capacity, with converter charges of about 15,000 pounds?

A. To the best of my recollection, the ladle I used there in 1877 was of the same size, if not the same ladle which was put in when the works were built in 1871, and this ladle was referred to always as a 10-ton ladle.

X Q. 218. To refresh your memory, is it not a fact that the Cambria ladle of 1871 was of 21,000-pounds capacity, and the converter charges 12,500 pounds, and that in 1877 the parts were rebuilt and the ladles increased to 28,000-pounds capacity for converter charges of about 15,000 pounds?

796 A. No. I have no recollection that such change was made in the ladle. I recall that about 1875, I suggested to the engineer of the works, Mr. D. N. Jones, a change in the general ladle arrangement to correspond with that I saw previously at the Steelton works, which included putting the ladle on a lift to facilitate pouring and get cleaner pouring in the ladle trough. This change was under way during the remainder of my term at Cambria, and was, I believe, installed some time after I left, and continued in use until the works were dismantled. I have no personal knowledge of it being used all that time, but saw it in use some time after my retirement from that works.

X Q. 219. It is testified by persons in authority at the Cambria works that the charging ladle was increased in 1877 to 28,000-pounds capacity. Please say on reflection whether this may not be correct.

A. It may be possible that a patch was added at the top of the original ladle to increase its holding capacity, which was generally deficient from the tendency to foul with skulls which our cupola ladles had at that time, but in view of the fact that the new ladle installment referred to in my former reply was in process of construction at that time, I do not believe, nor can I recollect that a new ladle was substituted for the old one during my time of service at the Cambria works.

X Q. 220. When you ran the Cambria works with a single cupola, how did you get sufficient metal for a converter charge?

A. At the time those works operated with a single cupola, the converter charge was obtained by making two or three taps from this cupola into the ladle, and thus securing a full charge, which one tap would not give us.

(Complainant's counsel now states that when request was made by defendant's counsel for the report made by Mr. Fry, he instructed his clients immediately to make search for the same, that he
797 has been informed by Mr. Gayley, who had the matter in charge, and to whom the report was originally handed by Mr. Schwab, that diligent search has been made, and that the same cannot be found. Complainant's counsel intends to produce Mr. Gayley for examination and cross-examination on the subject of this search.)

X Q. 221. When you severed your connection with The Cambria

Iron Company, the defendant herein, it was on the written demand of the general manager, was it not?

A. I do not remember having received a written demand, although I may have received one, but the demand was made during a conversation between the general manager, the late D. J. Morrell, and myself. In this conversation he requested me to remain a month or two to assist my successor in getting in touch with the details of the work, if the latter found that I could be useful to him.

X Q. 222. Your successor was Joseph Hartshorne, who had been your assistant, was he not?

A. Yes; my immediate successor was Mr. Hartshorne, who up to that time, and for a considerable time previously, had been in charge of one turn or shift of the open-hearth departments, which work was under my general supervision. In that sense only he was my assistant, and not in connection with the Bessemer department.

X Q. 223. Will you examine the paper I now hand you, and say whether that is not a true copy of a letter delivered to you in 1881 from the general manager of the Cambria Company, requesting your resignation?

(Complainant's counsel states that the letter which is presented to the witness is a letter written by a third party and represents simply the opinion of this third party, who not being under oath, and not being present, cannot by this indirect, and counsel thinks very unworthy proceeding, have his statements introduced in evidence. The question is one which is in violation of all the rules of evidence, it is obviously improper and unwarranted, and complainant's
798 counsel therefore instructs the witness that he should not answer the question.

To which counsel for defendant replies that he considers it eminently proper to bring before the court the relation which this witness bore to the defendant, and the circumstances under which he left its service, to the end that his feeling toward defendant may be understood. And in view of the fact that the witness has expressed his inability to recollect the circumstances attending the severance of his relation with the defendant company, it is submitted that it is proper to refresh his recollection by submitting to him the alleged letter calling for his resignation.)

A. I would state in a general way that in my answer to X Q. 221 I do not deny having received a written demand for my resignation, but on the contrary say "I may have received one." The paper you hand to me indicates plainly to me that I did receive from General Manager Morrell a written demand for my resignation, which I immediately complied with in writing, a copy of which I do not now have within reach. His request for me to remain a month or two to assist my successor in getting in touch with the details of the work should be a sufficient indication of the kindly relations which continued to exist after my resignation, and which continued until he died. My letter to him tendering my resignation conveyed also my grateful thanks to him for the kind-

ness and consideration he had extended towards me during the nearly thirty years of my service.

X Q. 224. You have referred to your service in connection with the Vulcan works. You were also discharged or requested to resign from these works, were you not?

(Complainant's counsel states that he is not at all informed what the answer of the witness to their question would be, nor what the facts are in this regard; but the question is so manifestly improper and irrelevant, that the witness is instructed, that out of re-
799 spect to the court and to himself and to counsel, he should not answer the question.)

A. By instruction of complainant's counsel my answer is declined.

X Q. 245. Are you the same John E. Fry, who in July, 1886, was indicted and convicted in the court of quarter sessions of the peace in and for the county of Schuylkill?

(Complainant's counsel states that as the indictments are for offenses not touching the credibility of the witness, the witness is instructed that he need not answer the question.)

A. Yes; I am the same person who was convicted in that court for assault and battery. The case was dismissed on my payment of costs.

(Complainant's counsel demands that he be allowed to see the paper which defendant's counsel has in his hand. The paper is submitted to complainant's counsel.)

Witness adds:

I will add to that, that I did all I could through counsel to bring the case to trial again for a complete vindication which was only a partial one in the verdict of the jury, but my efforts failed, and the case was settled on my payment of the court costs, as above stated.

Adjourned to meet July 24, 1897, at 10.30 a. m.

800 PITTSBURG, *April* 24, 1897.

Met pursuant to adjournment.

Present: As before.

Redirect examination by complainant's counsel:

R. D. Q. 246. Will you state whether since you left your employment at the Cambria iron works, your relations have been friendly to or in anywise hostile to the defendant company?

A. Not in the least respect, but on the contrary, I take great gratification in their continued success. I know of no officer of that company who entertains hostile feelings towards me. Certainly I have none toward any of them.

R. D. Q. 247. Have you ever been employed by the defendant company since you left their employment as superintendent, and if so, when and how?

A. Not in the general sense of the term comprehending any continuous employment. At the time of the great disaster which befell Johnstown and the Cambria works, on the 30th of May, 1889, the then president, the late Edwin Y. Townsend, requested me to go to the works and ascertain to the best of my knowledge the extent of the loss due to destruction at their main works. At the time this request was made of me, which was on June 2, 1889, I was called into their directors' room by the president, and one of their directors, I believe a Mr. Joseph Wharton, to look at a blue print which showed a general view of all their works in the vicinity of Johnstown, and to give them, from my knowledge of the locality and the works, based upon the best information I had gathered from the press dispatches up to that time, an estimate of what I thought had been the damage at their main works. My estimate at the moment was a quarter of a million dollars. Mr. Townsend told me that "the talk on the streets" was that the loss was four or five millions; that his assistant, Mr. Stackhouse, had started to Johnstown on Friday afternoon, May 30; that he did not know if he had arrived, and requested me then, as before stated,
801 to go on this service to Johnstown. He said he would arrange transportation, which he did. He asked me if I needed money. I told him I had plenty for the purpose. He directed me to telegraph him my estimate of the losses after I had consulted with Mr. Stackhouse, if the latter were then alive, and send my bill for my services. I performed the duty, presented my bill, which was paid by their check, I believe, accompanied by voucher, which I signed in receipt. If this may be considered being employed by them, in the sense that they would have the confidence in me to employ me, then I have been employed by that company since I left their service in 1881.

JOHN E. FRY.

PITTSBURG, *May* 3, 1897.

Met pursuant to agreement of counsel.
Present: Counsel as before.

Testimony of William Golding.

WILLIAM GOLDING, a witness produced on behalf of the complainant in rebuttal, having been duly sworn, testifies as follows in answer to questions by complainant's counsel, Mr. Bakewell:

Q. 1. State your name, age, residence, and occupation.

A. William Golding; age, 50; residence, Trenton, New Jersey; occupation, manufacturer of potters' materials.

Q. 2. Have you ever been engaged in the manufacture of steel at the works of the Pennsylvania Steel Co. at Steelton, Pa., and if so, when were you there engaged, and in what capacity?

A. I was so engaged between July, 1871, and July, 1881; the first four years as foreman and blower, the last six years as superintendent of the Bessemer department.

802 Q. 3. During all this time, as I understand you, your duties were in the Bessemer department at the works?

A. Yes, sir.

Q. 4. During that time, from what furnaces was the metal obtained at that works for use in the Bessemer converters?

A. Beside the No. 1 and 2 furnaces of the Pennsylvania steel works, we used various irons from the Cornwall district, Pennsylvania, and foreign pig iron.

Q. 5. In what furnaces was the iron melted for use in the converters?

A. In cupolas.

Q. 6. Into what was the iron tapped from the cupolas?

A. Into a receiving ladle.

Q. 7. Of what size?

A. About 18,000 pounds capacity.

Q. 8. What was the capacity of the converters?

A. 12,000 pounds.

Q. 9. Will you state whether this ladle was designed for or used for securing uniformity of the converter charge by mixing.

A. It was not.

Q. 10. Was such mixing necessary for the molten metal to be charged into the converter?

A. No.

Q. 11. What was the practice at the Steelton works about draining this ladle?

A. As a matter of experience, the ladle was generally drained at each vessel charge.

Q. 12. Was it or was it not the practice to leave a considerable pool of metal remaining in the ladle to secure advantages of mixing?

A. It was not.

Q. 13. If there had been any advantage considered in the works or practiced by maintaining a body of metal in the ladle for
803 the purpose of mixing or getting uniformity, would you have known of the same?

A. It certainly would have occurred to me.

Q. 14. If there had been any advantage in it?

A. Yes.

Q. 15. How long was this ladle of which you speak, used?

A. Similar ladle to the one which you describe was used the whole ten years of my term there.

Q. 16. Near the end of your work at Steelton was there any enlargement of the converters and ladle?

A. During my last year a second Bessemer plant was designed in which the capacity of the converter was increased one-half, and three converters were used instead of two, more than doubling the capacity of the No. 1 plant. To the best of my knowledge the ladle was increased in the same proportion.

Q. 17. Who designed the enlarged converters and ladle?

A. Myself.

Q. 18. And did they continue to be used after you left the works?

A. About 18 months after I left I made a visit there, and found the plant operating as to ladles and converters as designed by me

Q. 19. Will you please state what was your purpose in the new plant in designing a ladle which, like the ladle of the old plant, should be larger than a converter charge?

A. It was our practice to have two or more cupolas in operation at the same time, and it was necessary that there should be a reservoir for the heats drawn from those cupolas; first, because the tap from one cupola would not be sufficient for a vessel or converter charge; secondly, in case of accidents or repair to vessels we made a reservoir for the molten metal, allowing us to continue the cupolas in blast.

804 Q. 20. Will you state whether you designed this larger ladle for any purpose of making the converter charges uniform by mixing or maintaining a pool in the ladle for the purpose of mixing?

A. The object of using the ladle for the purpose of a mixer was not once thought of by me, nor by any one as far as I know.

Q. 21. What was the occasion of your revisiting Steelton about 18 months after you left?

A. I went at the request of Manager Bent, and also because I wanted to see the works.

Q. 22. At the time of your revisit to Steelton how was this larger ladle used in respect to the amount taken out of it and charged into the converter?

A. During my stay there, a half day in the Bessemer department, I noticed that the converters were waiting for charges from the ladle.

Q. 23. Will you state whether the ladle was drained or otherwise, in providing the charge for the converter?

A. As a matter of fact, I cannot state that the ladle was drained from observation, but from my experience I would naturally infer that since the converter was waiting several times for a charge, that as soon as a charge had accumulated in the ladle it would be at once emptied.

(Defendant's counsel objects to all that portion of the deposition of this witness relating to operations prior to July, 1881, as incompetent and not in rebuttal, and cross-examines without waiver of objection.)

Cross-examination by defendant's counsel:

X Q. 24. It is in evidence that the Pennsylvania Steel Company started up a new Bessemer plant September 12, 1881. Is this the plant to which you have referred as containing the large reservoir ladle?

A. It is.

805 X Q. 25. Was your visit of half a day to the Pennsylvania works your only visit after July, 1881, when they were in operation?

A. In my answer you refer to, I believe, I stated that I spent half a day in the converting department. In addition to that, I spent most of the previous day, which was Sunday, looking over the Bessemer plant in general.

X Q. 26. Was your half-day visit to the Pennsylvania works your only visit to the converting department when in operation after 1881?

A. Yes, sir.

X Q. 27. What part of the day Monday did you spend in the Pennsylvania converting department?

A. As far as my recollection goes, I should say between 10 in the morning and 4 or 5 in the afternoon.

X Q. 28. What was the capacity of the Pennsylvania reservoir ladle designed and built in 1881?

A. About 30,000 pounds.

X Q. 29. What was the usual charge of the converters with which the Pennsylvania reservoir ladle was used in 1881?

A. 18,000 pounds.

X Q. 30. Is there a fixed or definite temperature at which metal is delivered from the cupola?

A. The temperature of melted metal from cupolas is quite uniform.

X Q. 31. Do you mean to be understood as saying that cupolas tapped at different times and different cupolas always deliver molten metal at one and the same temperature?

A. I mean to say that since our practice is to charge all cupolas with the same mixture of iron and the same proportions of iron and fuel, and using the same blast pressure, after the first two heats from each cupola the charges will be quite uniform.

806 X Q. 32. Do you not in your practice have at times cupolas which melt badly or deliver relatively cold metal?

A. We have very little trouble of that kind. A cupola causing trouble of that kind is a rare exception.

X Q. 33. At the Pennsylvania works what was the usual tap from the cupola in 1881, and later when you visited the works?

A. From 5,000 to 8,000 pounds.

X Q. 34. Am I right in understanding your answer 19 to mean that when the 30,000-pound ladle of the Pennsylvania works was designed in 1881, it was intended to serve as a reservoir for molten metal drawn from either or both of the cupolas, in the case of accident or other cause which prevented the converters from taking the metal at once?

A. You are partly right, but my answer includes more than that.

X Q. 35. But in fact the 30,000-pound Pennsylvania ladle of 1881 was designed, was it not, to receive and hold the molten metal from either one, two or more of the cupolas, if accident or other cause rendered it necessary to hold back this molten metal to await the demand of the converters?

A. While the ladle was designed to accommodate both the converters and the cupolas, as a matter of fact, or experience, the cu-

polas were more often accommodated, since the converting capacity was generally in excess of the melting capacity.

(The answer objected to as irresponsive, and the question is repeated.)

(Complainant's counsel states that the question is asked as to the design or purpose, and it is submitted that the witness has very fairly and fully answered the same.)

X Q. 36. Question repeated.

A. I am satisfied with the answer I have given.

X Q. 37. When you designed the 30,000-pound Pennsylvania ladle in 1881, was it not your purpose to have it receive and
807 hold molten metal from one, two or more of the cupolas at one time?

A. It was.

X Q. 38. And it was your purpose in designing the Pennsylvania ladle in 1881 to have it hold in reserve the molten metal from the cupolas until the converters were ready to *ready to* receive such metal?

A. That was part of the purpose.

X Q. 39. And, as a matter of fact, this 30,000-pound Pennsylvania ladle, designed in 1881, and witnessed in operation by you 18 months later, was adopted, was it not, to receive and hold taps from two or more cupolas, or several taps from one cupola?

A. Yes.

X Q. 40. When you saw the Pennsylvania ladle in use subsequent to 1881, were the cupola taps drawn into it at random when ready for tapping?

A. Yes; provided the ladle was not already full.

X Q. 41. In answer 35 you have referred to the large Pennsylvania ladle, designed to "accommodate" both the converters and the cupolas. Will you explain for the court what you mean by this accommodation?

A. If there were no intermediate ladle, it would be necessary to run each tap from cupola to converter direct, which would necessitate the converters waiting for several taps, and also scull up runners or troughs considerably. The cupolas are accommodated by having a receptacle that will contain several taps, thus allowing them to be kept in blast.

X Q. 42. By being "kept in blast" I suppose you mean that the cupolas are enabled to start again immediately after the molten metal has been tapped out?

A. The object rather is not to have the cupolas out of blast at all, but to keep on melting all the time.

808 X Q. 43. Will you explain a little more fully how it was that the large Pennsylvania ladle enabled the cupolas to remain in blast?

A. By giving greater capacity for the taps. I would add further that the ladle while in operation becomes constantly reduced in capacity, because of the slag adhering to the sides.

X Q. 44. May it not be a fact, as testified to by other witnesses in

this case, that the Pennsylvania ladle of 1881, which you saw later in use, was of from 35,000 to 40,000 pounds capacity? I will ask you to refresh your recollection on this point.

A. With a proper thickness of refractory lining, I think not.

X Q. 45. Have you stated the capacity of the ladle from any records or data, or merely from recollection?

A. From recollection only.

X Q. 46. How many cupolas were in use at the Pennsylvania works, in connection with the Bessemer plant, as to which you have testified?

A. The original design had four; that is, four cupolas were built.

WILLIAM GOLDING.

809 PITTSBURG, *May* 5, 1897.

Met pursuant to adjournment.

Present: Counsel as before.

Testimony of John S. Kennedy

JOHN S. KENNEDY, a witness produced on behalf of the complainant in rebuttal, being duly sworn, testifies as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence, and occupation.

A. John S. Kennedy; age, 39 years; residence, Chambersburg, Pennsylvania; occupation, blast-furnace and mining engineer.

Q. 2. Have you ever been employed by the Pennsylvania Steel Co., and if so, when and where, and in what capacity?

A. I was first employed by the Pennsylvania Steel Co., as mining engineer and chemist in their mining operations in Virginia from 1880 to 1881. I was then ordered to Steelton, where I was for several months chemist in the laboratory, was then transferred to the blast-furnace department as assistant superintendent, which position I held for one year, when I was made superintendent of the furnaces of the company. This position I held until my resignation in April, 1887. I was at the Steelton works in all from November, 1881, until April, 1887.

Q. 3. What was done with the pig metal produced from the blast furnaces under your charge at Steelton?

A. The Bessemer iron made by me was cast into pigs and loaded on cars for shipment to the converting works. If it was not suitable for conversion into Bessemer steel, it was sent to the other departments of the works, or returned for remelting in the furnace.

Q. 4. Did you have any connection with the operations of the Bessemer departments, or interest therein? If so, please explain what?

A. I had no connection with the Bessemer department,
810 other than it was my duty to make a suitable iron and follow it up closely. I visited the Bessemer frequently to see how my iron was working.

Q. 5. At the Bessemer works how was the iron prepared for the converter?

A. The irons were carefully selected from the different piles to make up the cupola charges; the iron was then melted in the cupola furnace.

Q. 6. Into what was the metal from the cupola furnaces tapped?

A. The metal from the cupola furnaces was tapped into an iron ladle which stood on a scale platform supported by a hydraulic ram.

Q. 7. Do you know what the capacity of this ladle was, or about what it was?

A. It was of 30,000 pounds capacity.

Q. 8. Do you know what the practice in taking the metal from this ladle, whether the ladle was drained or not?

A. I have often seen the ladle drained in pouring into the converter.

Q. 9. How did the capacity of this ladle compare with the amount of metal required for a converter charge?

A. It did not hold two full charges.

Q. 10. Will you state whether you know the purpose of making the ladle larger than one converter charge?

(Objected to as incompetent.)

(Question withdrawn.)

Q. 11. Will you state whether there was any purpose of using this ladle as a mixer for mixing the metal that was poured therein?

(Objected to as leading.)

A. I never knew of the ladle being used for mixing purposes. If such was the practice I would have known it.

Q. 12. As a matter of fact, were the conditions of its use such that it could do any substantial or appreciable mixing or equalizing of the charges for the converter?

811 A. No. The capacity of the ladle was so small and the size of the pool of metal, when there was a pool, was of such varying size that I do not see how any mixing could be accomplished.

Q. 13. Was there any need of mixing the irons in the ladle in the Steelton practice?

A. No. The irons were carefully selected and mixed for charging the cupolas.

Q. 14. Was it the invariable practice of the Bessemer works at Steelton to maintain a pool of at least 5,000 pounds of metal in this ladle?

A. It was not. The ladle was often drained.

Q. 15. If there had been any advantage in maintaining a pool of molten metal in the ladle what interest would you have had in this advantage?

A. If there had been any advantage I would have known it and it would have aided me in my work at the furnaces.

Q. 16. Were you in any way responsible for the quality of metal

produced by the Bessemer works, that is, what relation did your work have thereto in this respect?

A. The blast furnaces and the Bessemer department were intimately connected. My iron had to satisfy the requirements of the Bessemer department.

Q. 17. If the Bessemer department did not produce good steel, was the blame ever laid or attempted to be laid on the blast-furnace department?

(Objected to as leading.)
(Question withdrawn.)

Q. 18. When was this ladle drained and when would there be some metal left in the ladle?

A. There would be no regularity in the process. The rate at which the converters take the metal does not always correspond with the rate at which the cupolas are melting. It would happen sometimes that the converters would take the metal very
812 rapidly and the ladle would be either drained or nearly emptied. In case the converting works were running slowly there would be an accumulation of metal in the ladle.

Q. 19. How many cupola furnaces did they have at Steelton running at the time you were there?

A. My recollection is that they started with four iron cupolas and added a fifth.

Q. 20. Have you been at Steelton lately, if so, when?

A. I was at Steelton about ten days ago.

Q. 21. Were they at that time using this charging ladle that you have testified about, if not, what were they using in place of it?

A. The mill has been remodeled within the last two years. The old ladle is no longer used. I saw a smaller ladle in use, which I was told held one heat.

Q. 22. You refer to a converter charge by the words "one heat," do you not?

A. Yes.

Q. 23. Is this smaller ladle which you saw at the Steelton works drained each time a converter charge is drawn therefrom?

A. I was only in the new mill a short time, and from the position of this ladle when it is emptied into the converter, should say that it was drained.

Cross-examination by defendant's counsel:

X Q. 24. What proportion of your time was spent in the converting department at Steelton?

A. I went there frequently, nearly every day; it was part of my duties to do so.

X Q. 25. Did you make daily written reports at Steelton, showing the output of their blast furnaces, the weights of the taps and the analyses of the iron, or either of them?

A. The weights of the casts were reported directly to me. In my daily reports to the general office I only reported the daily tonnage

of each furnace and the grades of iron. I got my analyses directly from the laboratory.

813 X Q. 26. As iron is drawn from a blast furnace during the cast, it varies in percentage of silicon and also in sensible heat, does it not?

A. It varies in percentage of silicon, and the rule is that the higher the silicon the hotter the iron.

X Q. 27. If, then, a furnace cast is run into a series of ladles, the iron in these different ladles will vary in the silicon content, and also in temperature?

A. There will be very little variation from the same cast in silicon and temperature.

X Q. 28. You mean, of course, in good furnace practice?

(This question and the preceding one, is objected to as not proper cross-examination.)

A. Yes.

X Q. 29. But if instead of dividing your furnace cast in separate ladles, you should run the entire cast into a vessel or pool, the variations in silicon and temperature would disappear, and you would have a uniform mass of metal averaged as to silicon and temperature, would you not?

(Objection continued, the witness not having been called as an expert in regard to blast-furnace practice, but in regard to the facts as to the practice at Steelton at the time he was there, and in pursuing this line of examination the respondent makes the witness its own.)

A. That is true.

X Q. 30. And if two or more blast-furnace casts were run entire into one vessel or pool, the same kind of equalization would take place in the entire mass, would it not?

(A general objection is hereby entered as to this line of examination.)

A. That is also true.

X Q. 31. When you were at Steelton, the 30,000-pound ladle received taps at random from a number of cupolas whenever they were ready to be tapped?

814 A. The iron ladle received the taps from one cupola or from two, three or four cupolas, as the operations of the mill might demand.

X Q. 32. Treating a cupola tap as a unit, about how many units are required to fill that old Steelton ladle?

A. My recollection is that the cupola taps averaged, say, 5,000 or 6,000 pounds a tap. It would take the iron from, say, five cupolas to fill the ladle.

X Q. 33. And this old Steelton ladle contained molten metal from a number of taps mixed or mingled together, the entire mass being homogeneous?

A. Certainly the metal would be homogeneous in the ladle.

X Q. 34. I understand this old Steelton ladle was emptied when the converter demand exceeded the supply from the cupolas?

A. Yes.

X Q. 35. And the accumulation of metal in the old Steelton ladle increased when the converter demand diminished in proportion to the cupola supply?

A. That would be so.

X Q. 36. Then this old Steelton ladle in which the taps were mixed and held was in a sense a storage reservoir or equalizer between the source of molten metal supply on the one side and the converter demand for molten metal on the other side?

(Objected to as indefinite.)

A. It was useful as a storage reservoir in case of an emergency.

X Q. 37. If that old Steelton ladle had been increased in size, would the method or principle of its use have been changed thereby?

(Objected to as not proper cross-examination, the witness having been called not as an expert, but to testify as to certain facts existing at Steelton at the time he was there. By this line
815 of examination, the respondent makes the witness its own.)

A. I do not see that any benefit would be derived by increasing the size of this ladle. My belief is that the old ladle was simply a mechanical convenience. If you make the ladle larger, it would still serve the purpose.

X Q. 38. And the larger the ladle is made, the greater the variation it would provide for between the metal production and the metal consumption?

A. No. If the vessel was largely increased, being an open vessel, either elements of variation would be introduced—namely, loss of heat by conduction, radiation, and the cooling influence of the air.

X Q. 39. Assume that that vessel had its capacity increased by increasing its depth without increasing the exposed surface of its metal and answer the same question?

(The former objection is continued to this and to any further questions that may be asked on this line. It is also objected to as hypothetical, it not appearing that such a ladle, as is indicated by the question, existed at Steelton.)

A. It would be impossible to say in what manner the variables mentioned as affecting the condition of the metal mentioned in the last question would be influenced by increasing the depth of the vessel.

X Q. 40. It is a common practice, is it not, to use lids on teakettles, on pots of various kinds, and on vessels holding molten metal to prevent loss of heat by radiation?

(Objection continued, and the question is further objected to as being indefinite as to time.)

A. It is customary to use closed vessels, and this has been done for many years.

X Q. 41. In selecting the cupola irons at Steelton, was each charge analyzed, or did you judge by the physical appearance?

816 A. I did not select the cupola irons at Steelton. They were selected by the superintendent of the Bessemer for the cupola charges.

X Q. 42. Do you know how the iron for charging the cupolas at Steelton was selected, or its chemical organization determined? I mean of your own knowledge?

A. I do. Each cast from the blast furnace was analyzed separately by averaging samples from a number of pigs of each cast. Iron that was purchased in the market was bought under guaranteed analyses and sampled from car-load shipments.

X Q. 43. Is it not a fact that knowing in a general way the character of the pig iron, it was selected for the cupolas by its physical appearance, largely by the fracture?

A. Such was not the case. While we could tell a great deal by the fracture, yet the irons were systematically analyzed. I would receive instructions to vary the percentage of silicon in my iron to suit the different requirements of the works.

X Q. 44. But you personally did not select or superintend the selection of iron for the cupolas, or keep any records of the same, did you?

A. I did not.

X Q. —. How soon did your pig iron usually reach the converting works after it was cast?

A. I should say from 8 to 12 hours after being cast.

X Q. 46. What is your present occupation?

A. During the last two years I have been engaged in expert work, examining and reporting on mineral properties, furnace plants, and metallurgical processes.

X Q. 47. In the manufacture of railway rails, it is particu-

817 larly important, is it not, to have the converter charges of definite and uniform weight, in order to produce ingots which can be rolled with a little scrap or waste?

(The former objection continued.)

A. Yes.

JOHN S. KENNEDY.

John S. Kennedy Recalled.

JOHN S. KENNEDY, being recalled for complainant in rebuttal, testifies as follows in answer to questions by complainant's counsel:

Q. 48. Of what use in equalizing the temperature of furnace casts would it be to maintain in an open-top receiving vessel or ladle a body of metal varying in amount but no larger than a converter charge?

A. It would be of no use. The varying amount of iron losing heat by exposure would introduce irregularities into the metal.

The varying size of the heat and the time of its exposure would be uncertain factors which would tend to cause irregularities.

Q. 49. What have you to say, then, as to the possibility of the practice with the large ladle at Steelton being of use in equalizing temperature by providing a pool into which the cupolas were tapped?

A. It would be of no use. The pool was not always present, and when present its size and temperature vary, thus tending to cause irregularities in the temperature of the heats. By causing these irregularities it would tend to be more of a detriment than a help.

Q. 50. What is the weight of a cubic foot of molten cast iron?

A. It is taken as about 460 pounds to the cubic foot.

Cross-examination by defendant's counsel:

X Q. 51. Answer Q. 48, assuming, however, that the vessel has a lid or cover?

818 A. If the vessel had a cover it would cool off more slowly than if the contents were exposed. The pool of metal is so small that I do not think it would be of much advantage.

X Q. 52. If there was the usual interval between heats, do you think the loss of temperature would be material with the vessel either open or closed?

A. I think so.

X Q. 53. How long do you know of molten metal being retained in open ladles or vessels in practicing the Bessemer process?

A. Of my own knowledge I only know of its being so kept for a few hours at a time.

X Q. 54. What is the usual length of time between converter heats or blows?

A. In the best practice one converter is turned up as the other converter is turned down, so as to make the intervals as short as possible. It would be only a few minutes between heats.

JOHN S. KENNEDY.

Testimony of James Gayley, Recalled.

PITTSBURG, *May* 3, 1897.

JAMES GAYLEY, a witness recalled in rebuttal by the complainant, being duly sworn, deposes and says as follows in answer to questions by complainant's counsel, Mr. Bakewell:

Q. 166. You are the same James Gayley who has already testified in this cause (Record, page 33)?

A. Yes.

Q. 167. While you were superintendent of the blast furnaces at the Edgar Thomson steel works, did you know of the practice referred to by Mr. Julian Kennedy in his answer to X Q. 39 of his deposition in this case, in which he says, that "when using for the converters metal taken directly from the blast furnaces with-

819 out passing through a mixer, sometimes when one furnace was on cold iron and another on extra hot iron, the two

were tapped close together, mixing the iron in the ladle"? If so, will you state how efficient such mode of operation proved to be in enabling the successful converting of direct metal?

A. I am familiar with the practice mentioned by Mr. Kennedy. When I first took charge of the Edgar Thomson works I practiced it to a considerable extent. We observed from it no improvement of the character of the steel. There was no continuity of composition. Each separate batch of metal was apt to vary just as much from the others as when we were running in the regular way, for this reason, that as the hot iron in the hearth of the furnace lies on top and is the first withdrawn, so by this method of mixing the product of two furnaces, it would follow that the hot iron from the one furnace was drawn into the hot iron from the other furnace, and the cold iron at the last part of the cast was run into the last ladle filled, which was the cold iron from the first drawn cast. As a matter of fact, it was not possible by any practical means to so arrange these ladles in filling as to obtain any practically useful results. The ladle would skull up. The practice was only useful for the blast-furnace man in heating up and getting rid of metal which came too cold from the furnaces at times when we were short of metal and had to take what we could get. It was not useful in improving the character of the steel.

Q. 168. Have you read the testimony of Martin Dowling, Watkin Y. Williams and Perry Mackey given in this case, concerning the disadvantages in the use of direct metal without the mixer at the Edgar Thomson works, and will you state whether these disadvantages were obtained with and notwithstanding the employment of the expedients mentioned in your last answer?

A. I have read the testimony you name, and I will state that such difficulties were not remedied by any process of mixing such
820 as described above. I mean to say, that we tried variations of this form of mixing, sometimes drawing but a third from one furnace into the ladle and two-thirds from another furnace, and sometimes only a quarter as near as we could gauge from one furnace and three-quarters from another, and then half and half, as described in my previous answer; but we obtained no beneficial results on the character of the steel, and we finally simply used the metal direct. The complaints received by me from the steel works about the iron were just as great, and as the results of the steel works' practice were sent to me daily I noticed that there was no improvement. The quality of the metal was irregular in composition, there being no continuity from one cast or mixture to another.

Q. 169. What then have you to say as to the efficiency of the mode of preparing metal for further treatment by merely mixing together non-uniform quantities of metal taken from two or more blast furnaces?

A. Such is the operation which I explained above as having been tried by us and from which we obtained no beneficial results.

Q. 170. Do you regard such method as being the same in principle or result as the Jones method of mixing?

A. It is entirely different in principle from the Jones method in that it does not aim to secure continuity by keeping the changes in composition and temperature within easily controlled limits for the converting mill; it does not recognize the principle of continuity or gradation at all, nor that such gradation could be made beneficial; nor does it provide for slowly occurring gradations which extend into a continuous operation from the beginning to the end of the week. The method described retains inherently the principle of abrupt changes and lacks the principle of continuity. Uniformity in results are only obtainable through uniformity in practice, and the Jones method by providing means for obtaining such uniformity in practice produces uniform results.

821 Q. 171. Notwithstanding the employment of the expedients referred to by you in answer to questions 2 and 3, will you state what was the percentage of second-quality rails which you obtained with such use of the direct metal as compared with the proportion of second-quality rails afterwards obtained by the use of the Jones mixing method?

A. I have endeavored to procure a statement of the percentage of second-quality rails made for the two years preceding and the two years following the introduction of the mixer, and I find, after careful search, that these records are not obtainable. All of our practice records during that period and before were destroyed by a fire in the vault where the records are kept. I, however, find from a correspondence with Sir Lowthian Bell of England, in 1891, that I stated to him that the percentage of second-quality rails had been reduced with a make of 6 per cent. from the direct process to 4 per cent. with the use of the Jones mixer process, and this information was derived from a careful investigation of the records at that time.

Q. 172. Will you state what are second-quality rails, and what is their cause? Will you also state what is the commercial importance of this fact, and if you can, illustrate your answer by producing a sample of a second-quality rail.

A. Second-quality rails are such as have defects which unfit them for service in the main line of railways, namely, such flaws as are liable to produce fracture of the steel. I present two samples, one showing a flaw on the head of the rail, the other a flaw on the flange.

The cause of second-quality rails is bad converting-mill practice, and this is occasioned in turn by abrupt changes in composition and temperature of the metal provided.

On the commercial side, many roads will not receive any second-quality rails in their orders, others will take 5 per cent. of them in their purchases at a reduced price, and they can only be disposed of at a reduction in price for use in switches and sidings, on

822 which there is little traffic and where they are used only for the storage of cars. Sometimes, to get rid of our stock of second-quality rails, we cut them into short lengths so as to avoid the flaws and rerolled such pieces in a small mill into rails of small section, such as mine rails; but this, of course, was a very expen-

sive practice. Further, to the manufacturer there is always a dread when making a large quantity of second-quality rails that there may be inherent weaknesses which might cause an accident and possible destruction of life.

(Complainant's counsel offers in evidence the samples produced by the witness and the same are marked "Complainant's Exhibit Second-quality Rails.")

Q. 173. How does the Jones method reduce the proportion of second-quality rails?

A. The Jones method reduces the proportion by eliminating abrupt changes in the metal, substituting continuity of changes, enabling each converter charge by its mode of working and its analysis to serve as an index of the quality of the succeeding charge, making the changes so gradual that the operation of the converting mill becomes one of practical uniformity. This factor of continuity goes on from day to day.

Q. 174. What have you to say to the statement of Mr. J. S. Robeson who, testifying for the defendant in this case, said that in 1893 and 1894 the weekly average of seconds at the Edgar Thomson steel works was 8½ per cent.?

A. The percentage given by Mr. Robeson is altogether too high. The report to which he refers not only included seconds, but also the bad rails which were cut up for scrap, and the average was about 6 per cent. at that particular time. This increase was occasioned by an experiment we were then making of rolling our rails directly from the ingots without reheating, and at the same time we had part of our heating furnaces torn out in order to put in new ones. We subsequently abandoned this practice, going back to the practice of reheating the blooms, as was in vogue when the
823 mixer was introduced, and the report of our seconds from day to day was then from three to four per cent.

Q. 175. I wish you would refer to the British patent of William Deighton, No. 3672 of 1873, read the same carefully, and state what meaning the description and drawing of that patent convey to you as a skilled blast-furnace man and steel-maker. You may state also what practical difference, if any, there is between the described method of Deighton and the Jones method of mixing.

A. While Deighton's description is not exact or full, yet from the standpoint of a practical blast-furnace man, the Deighton apparatus is obviously intended to be operated in only one way, and the way that would commend itself to practice, viz., to cast two or more furnaces at one time into the receiver, withdraw the converter charges, and then when the usual time of four or five hours between casts had elapsed the same operation would be repeated. As to differences—the Deighton would not give uniform metal for the converters, as the temperature would change greatly and the changes would be abrupt from charge to charge. Unlike the Jones method of mixing, it does not take care of casts of varying composition by making the changes so gradual as to lose their identity. It does not even recognize the fact, as in Jones' method, that changes in

metal charges to converters are easily controlled if made gradually, nor is there that element of continuity of composition and temperature which is the design and result of the Jones method.

Q. 176. Why do you say that the way in which the Deighton apparatus would be operated would be by tapping the furnaces together into the receiver?

A. When several furnaces are run together, it is the usual method, other things being equal, to tap substantially at one time. It makes the unpleasant work of casting to be done at one time, and then it is done with; and as a certain amount of skull would form in the runners from the furnaces to the receiver, there
824 would be less waste in tapping at one time, and less labor would be required to clean the troughs.

Q. 177. Why do you say that the Deighton apparatus was intended to be used by draining the receiver before recharging the same again with molten iron?

A. It would have been inoperative if worked on any other principle.

Q. 178. Why?

A. Deighton's receiver is an open top vessel, and by filling it at one time and then putting coke dust on top, as is the usual practice, then draining out in converter charges, on filling again at the regular casting time, the coke dust and graphite or "kish" from the metal could be scraped off and a fresh layer of coke put on. Whereas, if the furnaces were tapped successively at intervals into the receiver, the metal flowing in would splash over the coke-dust covering, and by chilling would make a skull on top of the metal. The next cast would also spatter in the same way, until the vessel would be skulled over with a crust of mixed coke, ash, and chilled iron, which could not be scraped off. In order to avoid this it would be necessary to charge the metal in at once, then add the coke dust, and then tap the metal out entirely and break down any incipient skulls before refilling; and the refilling should begin as soon as the vessel is drained out in order to bring the coke dust to the top to be scraped off. This we see in our practice at the Edgar Thomson works in filling ladles, where, if the ladle is filled when any coke refuse still remains in it, we are obliged to dump that ladle as quickly as possible in order to avoid skulling. The hard and fast rule at our works is that after pouring out the metal from the ladles they are put on a side track and the refuse is scraped out of them before they are refilled. I therefore conclude that whereas the Deighton apparatus operated in any way would present some practical difficulties, it would be absolutely inoperative if worked otherwise than by draining it after each filling.

825 Q. 179. Mr. Morgan has said in his testimony that in an experimental apparatus which he used at defendant's works for the purpose of trying Deighton's method, he applied to the apparatus a cover which he says is simply an equivalent of charcoal or coke dust used for retaining heat in foundry and furnace practice for years. Will you state whether in your judgment in doing

so he was fairly reproducing what is described in the Deighton patent?

A. The placing of the cover, as described by Mr. Morgan, over his fixed receiver at the Cambria works, was not employing the construction indicated in the Deighton patent. I have already stated that Deighton used an open receiver which shows that he did not propose to keep the metal in the receiver any length of time, but to tap it as quickly as possible, and that he did not intend to make the operation a continuous one, since otherwise his receiver would have skulled over.

Q. 180. Do you conclude that in making this experiment to which I have referred, Mr. Morgan did not follow the principle of operation of the Deighton patent?

A. Mr. Morgan did not follow the principle of operation that the Deighton patent would indicate to a practical man.

Q. 181. Can you state any fact in your own experience which would indicate that in the absence of some specific purpose for doing otherwise, the natural way to operate a metal mixer would be to fill it, and then to drain it substantially before filling it again?

A. Yes, I can. I remember very clearly the occasion of first filling the Jones mixer at the Edgar Thomson works. Without any conference with Capt. Jones, the inventor, we had concluded at the furnace department that the way it would be operated, would be to fill the mixer up, drain it out entirely and then fill it up again; and as a matter of fact, after being filled, we stopped casting,
826 and I gave orders to draw no more metal until the mixer was nearly empty, and just long enough before so that we could charge it a second time as rapidly as possible. I recall that standing alongside of the mixer with Capt. Jones, when two or three heats were withdrawn, he asked me why there were no filled ladles there to keep the mixer full. I replied, that I supposed that the mixer would be drained before recharging, and that I had not given orders for any metal to be supplied. Capt. Jones replied, that his intention was to keep the mixer always full, and to issue orders to that effect. These orders were issued, and from that time on this has been the rule for operating the mixer. As this was at variance with what I had conceived as the method of operation, it impressed itself very clearly upon my memory.

Q. 182. Will you please refer to the paper published in the Journal of the Iron and Steel Institute for 1876, put in evidence by the defendant, wherein Mr. Snelus is reported to have said as follows:

"There was one point that had not been mentioned; with all the care that could be exercised at the blast furnace, he did not think it was advisable to take the iron from one furnace, but they might get an average mixture by taking it from two. They found no difficulty in taking three tons from one furnace, stopping the furnace up again, and then going to another."

What have you to say as to the practicability of doing as is suggested in the quotation I have just read?

A. It is not practicable as a furnace operation to tap the furnace in the manner described. Mr. Snelus must have been misunderstood. The practical method of obtaining such a small quantity of metal would be to tap the furnace in the regular way and at regular hours, and when so tapping to divert two or three tons from the main runner into a ladle, allowing the remainder to go into the pig beds in the usual way. There was no method in vogue at that time, nor is there any today where a like amount of iron can
827 be tapped from a blast furnace and the furnace stopped up and this repeated as a continuous operation. I remember meeting Mr. Snelus in 1890 in company with Sir Lowthian Bell, and explaining to them at the Edgar Thomson works the operation of our metal mixer. We discussed the subject thoroughly and he made no mention of having practiced such a procedure as described.

Q. 183. What are the practical difficulties of stopping the flow of metal from a blast furnace before the furnace is completely drained?

A. The difficulties are as follow: Before draining, the metal would be flowing out of the tapping hole, and it is practically impossible to stop with clay against iron. We are careful in practice to stop only against cinder or coke as the iron boils violently when coming in contact with damp clay, and the hole is insecurely stopped so that the metal may break out between casts when the workmen are unprepared for it. Again, it is important to ram the clay back to the far end of the hole, as the metal and cinder tend to eat forward. If stopped against cinder or coke this can be done, but not against iron, for the iron chilled in the hole soon becomes red-hot by heat conduction and there is danger of breaking out. Generally when iron so breaks out it boils in the runner and may cause a suspension of operation for a day or longer. Even with a mechanical stopper recently devised this same precaution against stopping the hole when the iron is running is carefully observed.

Q. 184. Will you please refer to the paper of Mr. Holley on the Direct use of blast-furnace metal in the Bessemer process, which has been put in evidence by the defendant, and state whether there is anything in that article which would suggest to those skilled in the art the Jones method of mixing metal?

A. Mr. Holley mentions two methods to produce metal
828 proper to supply to a converter, one of which is to mix a number of blast-furnace charges together so as to reduce the irregularity to a minimum. I can see nothing in this suggestive of the Jones method. He does not describe any method by which this could be carried out, but his method of operation as interpreted by a practical man is to mix a small quantity of metal together, withdraw it for converter use before it chills and then make up another batch; each batch necessarily differing in composition from the next. There is no suggestion of a pool of metal to be maintained, nor of obtaining heat by successive additions balanced by withdrawals of small portions, as in the Jones process. The Holley system might be summarized as a preparation of successive batches

of metal, each uniform in themselves, but differing from each other, there being no continuity established from batch to batch, his idea being principally to make uniform a single batch without any regard to successive batches.

Holley's method of treating a large quantity of metal is in a receptacle operated and heated like a reverberatory furnace. During the considerable interval of time required to drain out a large body of mixed metal from the receptacle, the metal would chill and the last portion drained might be too cold for use. It is impossible to fill a vessel up and to withdraw successive charges without the last charges varying so much in sensible heat from the first charges as to act in the converter like two different metals. We experience this result in our own mixer every Saturday when we drain it, for the last charges withdrawn are generally so cold that they need to be side-blown.

It was, therefore, natural for Holley, working on the line of mixing up and successively draining batches of metal, in order to keep the batch hot to the end, to describe the use of a reverberatory furnace, in which the metal could be heated, and his description of such furnace shows that this was the line of working which he had in mind.

829 Q. 185. What have you to say as to the principal function of the Jones mixer, whether it is for storing or for mixing the metal from the blast furnaces?

A. The Jones mixer was not installed as a reservoir at the Edgar Thomson steel works, nor has it been considered to be specially valuable for that purpose. At the starting of the mixer the attention of everybody concerned was directed to the analyses of the successive ladles taken from it in order to observe the character of metal it produced. The reservoir feature and the advantage in supplying uniform weights to the converter are comparatively unimportant.

Q. 186. What is the Jones apparatus called at the Edgar Thomson steel works, and what is similar apparatus called at other steel works where it has been installed?

A. Wherever this mixer has been installed it is called a "mixer." That is the shop name and in the trade generally it is spoken of by that name. Mixers are used at the works of the Maryland Steel Co., Cambria Iron Co., Illinois Steel Co., Cleveland Rolling Mill Co., Edgar Thomson steel works and the Duquesne steel works, and I am informed they are installing one at the works of the Pennsylvania Steel Co., at Steelton, Pa.

Q. 187. When were the mixers to which you referred in your last answer built?

A. The Edgar Thomson Steel Works' mixer was built first. The others have been built since. The last company to install one was the Pennsylvania Steel Company, at Steelton, Pa., whose mixer, I understand, is not quite completed.

Q. 188. One of the witnesses in this case, Mr. Joseph Morgan, Jr., has stated:

"On the other hand, modern furnace practice has so increased

the regularity of the iron output as to its chemistry that we should count upon blowing nine heats of every ten without much
830 difficulty so far as heating elements are concerned, and with a far less loss from irregular quality of metal than from a practice which prevents accurate measurement of heats, so that for this use a reservoir might be dispensed with for much direct work.

For these considerations, as an engineer, I consider that the direct process today, for its regular working, depends much more for its success upon the storage reservoir and its further function of exactly measuring heats than upon the mixing incidental to storage."

What have you to say as to the correctness of Mr. Morgan's conclusion that the direct process depends much more for its success upon the storage reservoir and its further function of exactly measuring heats than upon the mixing effects?

A. I presume that Mr. Morgan's answer refers particularly to his experience as an engineer. I am quite sure that had he practical knowledge of the operation of blast furnaces and the supply of metal to Bessemer converters he would not have made such a statement. The use of a reservoir simply as such, between the blast furnaces and converters, is really a step backwards, from the fact that it is eminently desirable to use the metal directly from the blast furnaces in order to take advantage of its high initial heat; whereas, the charging of it into a reservoir permits of a large amount of the initial or sensible heat to be radiated and lost. Such loss must be supplied by an increase in the content of silicon in the metal, and the supplying of such silicon means a material increase in cost at the blast furnaces, silicon being the most expensive metalloid that is introduced into iron during the smelting operation. As a matter of fact the practical men who first introduced the use of molten metal from blast furnaces into the converters without remelting in a cupola took the metal as quickly as possible from the furnace to the converting department in order to avail themselves of the sensible heat.

And, further, I might say that, following out Mr. Morgan's statement of the advantages being only of value as a reservoir,
831 and for exactly measuring heats, it seems to me as a practical man, and I presume it would occur to any engineer, that Mr. Morgan's company went to an entirely too great expense in installing such an apparatus as they did, if they simply wished to secure the benefits of a reservoir to procure exact weights, since a vessel of one-tenth of the size, or less, would have answered that purpose.

Moreover, in the use of the mixer, the ladles from the blast furnaces must wait their turn before being emptied into the mixer to replace the withdrawals, the same as they used to wait their turn in the direct process before being emptied into the converters.

The ladles in the "direct-metal" process without the mixer were sufficient and suitable reservoirs, regarded solely as such, and in my experience with them before the introduction of the mixer,

lasting over two years, I never found them unsuitable or inefficient in this regard. There was never any trouble when using the ladles in having an ample supply for the converters. The mixer never would have been introduced at our works on account of its reservoir functions. The whole thought was mixing; there was no need of it for any other purpose.

Of the many steel-makers who have visited the works and in my company have seen the mixer, I have never heard any of them speak of it except in regard to its work as a mixer.

Q. 189. In installing the mixer at the defendant's works, was there provision made to adapt it to perform the function stated by Mr. Morgan—namely, to serve as a reservoir for the purpose of "measuring heats accurately"?

A. No. No scales were put in front of it, as there would have been if this function had been intended.

Q. 190. What have you to say to the statement of Mr. Morgan, in answer to Q. 11 of his deposition, that the saving which you and Mr. Lauder have attributed to the mixer is really due to the
832 change from inaccurate to accurate practice, occasioned by the so called reservoir advantages of the mixer?

A. The accurate practice to which Mr. Morgan refers is that of measuring the heats accurately. The metal mixer erected at the Edgar Thomson works was by transportation route about one-half mile from the converting mill; and, while we could pour the charges more accurately from the mixer than could be done from the blast furnace direct, yet the charges at the converting mill vary as much today as when we were using the direct process. This is owing to the fact that the metal is transported to the converting mill after it has lost heat in the mixer, and skulls more readily. After the introduction of the mixer, I observed from careful weights taken that the amount of scrap coming from the converter-charging ladles was even greater than what it was in the ordinary direct process. But notwithstanding the fact that with our mixer we do not obtain the advantages of a reservoir described by Mr. Morgan, yet it has been found extremely valuable, and it has been operated constantly because of its mixing function

Q. 191. What have you to say to the suggestion that the circular shape and the central location of the trunnions of the defendant's mixer is such as to prevent agitation of the contents and mixing of the metal?

A. The location of the trunnions is a matter of small importance as regards mixing in the construction of the mixer. In the Jones metal mixer the mixing occurs not only by the disturbance of the metal in withdrawing the metal charges, but by the pouring in and principally by the natural diffusion and the currents of travel produced in the hot liquid through radiation of heat. As the heat radiates from the exposed sides of the mixer, the metal contiguous thereto flows down around the sides, then in and up through the center, and as long as radiation of heat goes on this current of tra.el is maintained. This is readily seen in a ladle filled
833 with molten metal, or in a glass of water in which sawdust is placed and which is heated. As soon as the heat is re-

moved the particles immediately begin to flow down the sides and up through the center. Hence, irrespective of any movement of the apparatus, the conditions for thorough mixing exist.

Q. 192. What have you to say to the suggestion of Mr. Morgan, that the saving obtained from the reduction in the quantity of defective or second-class rails is often balanced by the labor and expense of providing and operating the mixer?

A. Such is not our experience.

Q. 193. Will you please refer to the stipulation of counsel in this case as to statements made by Mr. Morgan, and state whether there is anything in the matters and figures therein contained, showing any reason why the use of a mixer was not desirable at the defendant's works prior to 1895?

A. It shows no reason why it was not desirable. They were producing about 75 per cent. of metal relatively to the production of ingots. The Maryland Steel Company operated their mixer when they had only sufficient molten metal from their furnaces to supply about one-half of what they needed. It has been frequently stated that since the introduction of the mixer at the Cambria works they have used large quantities of cupola metal along with mixer metal, and I can therefore see no reason why they should have hesitated to install a mixer.

Q. 194. What have you to say to Mr. Morgan's answer to Q. 164, wherein he says:

"The smelting furnace and melting cupola differ in proportions of their lines forming the interior, but are similar in functions of furnishing molten metal, one from the ore and the other from pig metal."

A. The similarity that Mr. Morgan notes between a blast furnace or smelting furnace and a melting cupola is a very broad one,
834 as the conditions under which metal is produced from a furnace make these appliances as diverse in their methods of operation as can possibly be. The material charged into a cupola furnace is an absolute guarantee of the character of its product. From the charge of a smelting furnace you can predicate nothing. A cupola furnace or a series of cupolas at one plant may vary in composition of metal produced from day to day, and often are made to vary, designedly in order to furnish the peculiar metal that is needed for refining or to work out the stock of pig metal in the yard, or to work off an accumulation of scrap by providing metal that will stand more scrapping at the converters, or to provide against changes in the weather, when, on account of the moisture in the air, a higher silicon metal is necessary. The changes are effected so readily in cupola practice that results can be gotten in about two hours.

In the blast furnace a condition that may necessitate a change may itself be entirely changed before the metal is produced from the furnace that was suited to that special condition, and this is not rarely but often the case. It is not possible, as in the cupola, to know, except within wide limits, what will be the nature of the metal that will be produced, as it takes from 18 to 24 hours for the

material to come through a blast furnace, and a sudden change in the humidity of the atmosphere would upset all calculations as to the character of the product. In cupola practice, in making the variations I have spoken of, all the cupolas in operation are made to vary at one time, and this uniform variation can be controlled; but the blast furnace not only varies from adjoining furnaces at given times, but practically at all times, and is not controllable. Blast furnaces of the same size and interior shape and charged with the same mixture and weight of ores will vary in the character of metal produced just as much as if all the above conditions were different. There is a certain individuality of operation associated with the blast furnace that is not the case with the cupola.

835 Q. 195. What have you to say to the suggestion of Mr. Durfee that the general practice in selecting pig metal for melting in cupola furnaces at the date of the patent in suit, was to receive the metal at the Bessemer works on cars which were unloaded promiscuously into large piles of irregular dimensions from which the metal was taken for remelting?

A. In reply to that statement I cannot conceive of any method of bringing metal to a converter mill in cars, unloading it in piles and then taking from different points of these piles metal to fill the charging buggies for the cupola, without a substantial mixing. The men would draw the charge from the cross-section of these piles for each cupola in turn, and could not do it without making a very intimate mixture of the metal before it was charged into the cupolas. Mr. Morgan has stated, that in his own works where this practice was employed only "suitable metal" was sent from the blast furnaces, and it is quite clear to my mind that the practice at other works would be the same as that adopted at the Cambria works.

Q. 196. One of defendant's witnesses in this case, Mr. J. S. Robeson, has stated that during the first part of his work at the Edgar Thomson steel works he never saw a variation of more than three-fourths of one per cent. of silicon in a cast of metal, and further in the same answer, that he does not recollect any similar figures as to sulphur, since the determinations of this element in the steel works' laboratory were not very frequent. What have you to say to this statement?

A. Mr. Robeson is in error. We did not analyze the different parts of a cast to find out the variation in the silicon, except in rare instances for special information. With respect to sulphur, we determined this element in every cast made.

836 Q. 197. Mr. Robeson again states in answer to Q. 29 that he has seen the side-blowing ranging from nothing up to 90 per cent. in 24 hours. Please state if this practice prevailed during the period mentioned by him.

A. I am quite sure that Mr. Robeson never saw such wholesale side-blowing as he mentions. I cannot recall such occurrence. We always have to side-blow the first heat blown in a converter after a new bottom is put on, because the temperature of the metal is reduced by the cold bottom. The second heat will blow hotter,

and the third one still hotter. Again, in very humid weather, which would affect blast furnaces as well as converter operations, we were apt to get a few casts of low silicon metal which would require side-blowing.

Q. 198. Refer to Mr. Robeson's answer to Q. 33 of his deposition in which, in discussing the answer to Q. 9 of your previous deposition, he says: "Considering this list in the light of the analyses of which I was acquainted in 1893 and 1894, I do not consider it an average list. The variations shown here are very gradual." What have you to say to this statement?

A. The best reply I can make is to present in evidence a complete monthly record of our regular mixer analyses for June, 1893, and April, 1894, giving analyses of every alternate converter charge taken from the mixer. They show that my first list was an average and usual one. In addition, I also present our regular records of the several furnace casts for April, 1894, in which is shown the time of cast, the letter designating the furnace, and the analyses. I have taken these records at random without any selection of particular months.

(Complainant's counsel offers in evidence the records produced by the witness, and the same are marked "Complainant's Exhibits Gayley's Records of Mixer and Furnace Analyses.")

Q. 199. Mr. Robeson, in answer 99 in reply to the question, what was the capacity of the ladles used for taking the metal from
837 the furnace to the mixer, replied as follows: "My impression is that they were about 20 tons." Was he correct?

A. We used ladles of 10 tons capacity.

Q. 200. Please state what meaning is conveyed to a skilled metallurgist by the words "molten metal for further treatment"?

A. He would understand that it refers only to metal that is to be refined.

Q. 201. Have you been familiar with the works of the Vulcan Iron Company at St. Louis, Mo.?

A. In 1880 to 1882 I was chemist for the Missouri Furnace Company in St. Louis, whose works adjoined the Vulcan steel works.

Q. 202. In the Vulcan steel works, did they use for their converters metal taken directly from the blast furnaces?

A. They did not. Their converters were supplied with cupola metal.

Q. 203. Have you ever been at the steel works at Terre Noire in France?

A. I have been; I was there in the year 1889.

Q. 204. What was the condition of those works?

A. When I was there they were simply running the plate mill in an indifferent manner. The engineer who showed me through the works explained that the rest of the plant was shut down because the company had gone into the hands of a receiver, and that they proposed to stop work entirely in a short time.

Q. 205. Have you visited the car-wheel foundry of A. Whitney &

Sons, on Callowhill street, Philadelphia, and have you seen the cupolas and ladle at that foundry?

A. I have.

Q. 206. Can you produce photographs showing the same?

A. I herewith present photographs showing two views of the apparatus in question.

838 (Complainant's counsel offers in evidence these photographs, and the same are marked "Complainant's Exhibits Photographs Whitney Cupolas.")

Q. 207. Can you produce photographs showing the Jones mixer at the complainant's Edgar Thomson works and Duquesne works?

A. I present photographs showing the mixer at the Edgar Thomson works, and likewise one at the Duquesne works.

(Complainant's counsel offers in evidence the photographs last produced by the witness, and the same are marked, respectively, "Complainant's Exhibits Jones Mixer at Duquesne and Jones Mixer at Edgar Thomson Works.")

Q. 208. Are both these mixers operated by the same method?

A. Yes, and they give the same results.

Q. 209 Do you remember a report which was made in 1890 for the Edgar Thomson steel works by Mr. John E. Fry, concerning the operation of the Jones mixer? If you can produce this report, please do so. If, however, it cannot be found, will you state the facts in this regard, and also state what were the contents of the report?

A. The reports made by Mr. Fry to Mr. Schwab were sent to me and were in my possession until I left the Edgar Thomson works, but I do not know what has become of them since. A most diligent search has been made, but they cannot be found. I read the reports very carefully at the time, and recall the conclusion arrived at by Mr. Fry with reference to the blast-furnace department, in which I was particularly interested, they being under my charge, which was in substance that in all his experience he had never seen more suitable metal provided for the Bessemer operation than was furnished from the Jones mixer at the Edgar Thomson steel works, and further before making this report, Mr. Fry made the same statement to me personally a number of times. This report was

839 a general consideration of the practice throughout the whole steel works, and the part relating to the metal mixer and metal furnished therefrom was an incidental feature of the report, the substance of which I have just given.

Q. 210. It appears in your testimony that you have been connected with the iron and steel business since you graduated from college in 1876. I wish you to state whether you have ever heard in connection with supplying cupola metal for use in the converters, of utilizing, for the purpose of mixing, the residuum of metal left in the cupola ladle after the converting charge is poured. State also whether if such had been the recognized practice in any steel works in this country you would have been likely to learn of it?

A. I had never heard of the practice of leaving some metal in the cupola-charging ladle for the purpose of mixing until I read the testimony of defendant's witnesses in this case. In all my visits to the various steel works of the country I have never heard it mentioned that such a practice was conducted, and I feel certain that if it had been I should have been familiar with it.

The residuum is the excess necessary to obtain the exact charge of the converter. Its sole purpose was to secure a sufficient weight and it was too small to have any mixing effect.

Q. 211. After the installation of the Jones mixer at the Edgar Thomson works, and prior to the installation of the mixer at the defendant's works, do you remember to have seen and conversed with Mr. Joseph Morgan on the subject of the mixer, and if so, when and where was the conversation and what was its substance?

A. I remember to have seen and conversed with Mr. Joseph Morgan at the Edgar Thomson steel works in the latter part of 1894, or early in 1895, and gave him fully of what information and experience I had in the use of the mixer and advised him as to the best location, which should be contiguous to the converters, and
840 while I may not have shown to him a drawing of the mixer we contemplated building, yet I remember telling him about it, explaining that it was to be cylindrical in shape, and was to have a capacity of 300 tons. I remember at the time that Mr. Morgan was doubtful as to the advisability of constructing a mixer of such capacity, and I explained to him the importance of it. The subject referred to was the metal mixer, spoken of as such, and no other term was used to designate it at that time.

Q. 212. How long did the conversation with Mr. Morgan on the subject of the mixer continue?

A. I presume about one hour.

Q. 213. Will you state whether at that time Mr. Morgan expressed any doubt as to the utility of the mixer for the purpose of the equalizing or mixing charges for a converter or any doubt as to this being the proper function of the mixer, or whether he suggested any other office which it performed?

(Objected to as leading and incompetent, and calling for negative testimony.)

(Question withdrawn.)

Q. 214. Will you state what was said at this conversation by yourself and Mr. Morgan, as to what work or office was performed by the apparatus at the Edgar Thomson works, and what was to be performed by the apparatus to be built by Mr. Morgan?

(Objected to as incompetent.)

A. That matter was not discussed by us.

Q. 215. What was Mr. Morgan's connection with the defendant company at the time of this visit?

A. Mr. Morgan was their engineer.

Q. 216. Prior to the installation of the Jones mixer at the Edgar Thomson works, do you remember to have visited the defendant's

Cambria works at Johnstown, and in company with Capt. William R. Jones, Mr. Joseph Morgan, Jr., and others, to have seen
841 apparatus for getting converter metal direct from the blast furnace? If so, state what you saw there, and what, if anything, was said by Mr. Morgan or others as to the purpose of installing such apparatus?

(Objected to as incompetent.)

A. I remember visiting the Cambria works with Capt. Jones in the year 1885, and was shown through the works, partly by Mr. Morgan and Mr. Fronheiser, and my recollection is now that Mr. Morgan did not go over to the blast furnaces with us. I saw their ladle tracks for taking the ladles to the cast-houses, hoods for drying the ladles by means of furnace gas, and these appliances so arranged as to be suited for the purpose of taking metal direct from the furnaces to the converters, and for which purpose they were installed. I believe now it was Mr. Fronheiser, of whom I asked the question why they did not begin, and received the reply that they were waiting to see what success we were going to have with it. The appliances were in such shape, as far as I could see at the blast furnaces, as to be ready for use any time. I recall now that after leaving the blast furnaces we went to Mr. Morgan's office, where he showed us the drawing of a new cupola he had designed. This was clearly impressed on my memory, as it was the first visit I had made to any large works after locating here.

Q. 217. At that time, what kind of metal were you using for the converter at the Edgar Thomson works?

A. Direct metal from the blast furnaces.

Q. 218. And what was the practice to which reference was made by Mr. Fronheiser, when he said that they were waiting to see what success you were going to have with it?

A. The practice of using metal direct from the blast furnaces.

Q. 219. Referring again to the visit of Mr. Morgan to the
842 Edgar Thomson steel works in the latter part of 1894, or early in 1895, will you please state what was the purpose of Mr. Morgan's visit as stated by him?

(Objected to as incompetent.)

A. The purpose, as I recollect, as stated by him, was to talk over the subject of a mixer, and we discussed along the lines indicated in a general way.

Q. 220. Will you state whether anything was said in the course of the conversation which showed that Mr. Morgan understood the purpose for which the mixer was used, and if so, state the same, and state whether or not Mr. Morgan stated anything which would indicate that he had in mind any other purpose or use for the apparatus?

(Same objection.)

A. As stated in my previous answer, the purpose for which the mixer was used was not discussed, inasmuch as both the purpose

and the methods of operation were well understood, and it was assumed on both sides that the whole method was understood, and it was not necessary to state specifically what the purpose was. I am sure that Mr. Morgan did not state anything that would indicate to my mind that he intended to use the apparatus which he intended to install, or that the apparatus which we were using, was for any other purposes than that applied by the term "mixer."

Q. 221. Will you please state what is the capacity of the mixer which the complainant company has installed at its Duquesne steel works?

(Objected to as immaterial.)

A. 250 tons.

Q. 222. Will you state whether in your conversation with Mr. Morgan at the Edgar Thomson works, to which you have referred, you told Mr. Morgan that the Jones apparatus had grave defects, or whether Mr. Morgan told you that the Jones apparatus had grave defects?

A. I made no such statement to Mr. Morgan, neither did he to me, nor was there anything in our conversation that would
843 lead me to believe that the Jones mixer was not an eminently satisfactory apparatus, and inasmuch as he purposed installing a mixer I should assume that it was. Moreover, Mr. Morgan's intention as to capacity he proposed to construct was less than what I recommended to him and was more nearly in accordance with the size, as I now recollect, of what had been constructed elsewhere.

Complainant's counsel offers in evidence certificates under the seal of the patent office of Great Britain, dated April 8, 1897, which are marked "Complainant's Exhibit Certificates from British Patent Office." Said certificates read as follows:

(Seal of patent office.)
(Five-shilling stamp.)

PATENT OFFICE, LONDON, *8th April*, 1897.

I, Cornelius Neale Dalton, comptroller general of patents, designs and trade-marks, hereby certify that the letters patent No. 2061, dated 4th September, 1856, granted to John Loude Tabberner, expired on the 4th of September, 1856, by reason of the non-payment of the stamp duty of 50 pounds.

(Signed) C. N. DALTON.

(Seal of patent office.)
(Five-shilling stamp.)

PATENT OFFICE, LONDON, *8th April*, 1897.

I, Cornelius Neale Dalton, comptroller general of patents, designs and trade-marks, hereby certify that the letters patent No. 685, dated 6th March, 1872, granted to Charles Denton Abel (a commu-

nication from Z. S. Durfee) expired on the 6th March, 1879, by reason of the non-payment of the stamp duty of 100 pounds.

(Signed) C. N. DALTON.

(Seal of patent office.)
(Five-shilling stamp.)

PATENT OFFICE, LONDON, *8th April*, 1897.

I, Cornelius Neale Dalton, comptroller general of patents, designs and trade-marks, hereby certify that the letters patent No.
844 3672, dated 11th November, 1873, granted to William Deighton, expired on the 11th of November, 1876, by reason of the non-payment of the stamp duty of 50 pounds.

(Signed) C. N. DALTON.

(Objected to as incompetent and immaterial.)

Cross-examination by defendant's counsel without waiver of objection:

X Q. 223. Is your testimony respecting the Jones process based on the language of the patent, or on the operations carried on at the Edgar Thomson works?

A. My testimony is based on the operation of the process as I know and have practiced it.

X Q. 224. Have you carefully read the Jones patent in suit, No. 404,414, and compared the operations at the Edgar Thomson works, of which you have testified, with the operations described in the patent, and particularly in the claims thereof?

A. During the period of my last examination, at the request of Mr. Kay, I read over the specification of the Jones patent. I believe that was a year ago. I do not recall that I have seen it since, nor do I recall that in describing the operations of the Jones method I have had in mind the character of the operations as described in the claims, my object being to describe the method as I know it by practical manipulation of it.

(In view of the preceding answers of the witness, all portions of his deposition referring to the Jones process are objected to as incompetent.)

X Q. 225. You have referred to the temperatures under the Jones process. Do you find in the Jones patent any statement as to temperatures, or any limitation as to how high or how low temperatures may run?

(Objected to as not proper cross-examination.)

The witness is handed a copy of the Jones patent.

845 A. Reference is made in the specification (line 1, p. 3) to the avoidance of sudden variations in the "quality of the metal supplied to the converters." The quality of the metal for such purposes includes variations in chemical composition and temperature of sensible heat, both of which are essential to the converter operation. I do not find anything in my hasty perusal of the pat-

ent that indicates anything in regard to limitation, and on page 2, line 40, I find the terms "uniformity in character of the metal," which comprehends both chemical and physical qualities.

X Q. 226. Then you do not find in the Jones patent any direct statement as to any limitation in the temperature either upward or downward?

(Objection continued.)

A. I would ask to what you refer with reference to the limitations.

X Q. 227. I use the word in its ordinary sense as indicating how high or how low in temperature the metal may be used in any part of the Jones process?

A. I really do not find in my hasty examination of these specifications anything that would indicate a limitation in temperature, any more than a limitation in constituents, the object being to correct the irregularities and the variable conditions as they are found to exist in practice.

X Q. 228. What do you find in the Jones patent specification determining or limiting the size of the blast-furnace charges delivered into the mixer?

(Objection continued.)

A. I do not find anything.

X Q. 229. Is there anything in the Jones patent fixing the amount or size of the ingoing charges of blast-furnace metal in relation to the size of the mixer?

(Objection continued to all this line of examination.)

A. I do not find anything specifically limiting this.

846 X Q. 230. What instruction does the Jones patent give as to the size of the blast-furnace charges entering the mixer?

A. It does not specify the exact number of tons that should be included in an addition.

X Q. 231. Is it not a fact that the Jones patent leaves you entirely in the dark as to the size of the charges entering the mixer and as to the intervals between the introduction of successive charges?

A. In the patent specification which was handed me I do not find any definite statements as to the size of the charges going into the mixer. It does mention that the mixer should be of a convenient size, holding 100 tons more or less, (specification, page 2, line 18,) and he provides that the operation should be carried on in such a manner that such variations in the quality of the metal should be avoided, (specifications, lines 1–3, page 3,) and in order to obtain such results from his metal mixer it would indicate that the operation of charging must be with such quantities as will produce these results, and the data is sufficiently clear to a practical man to give him a good basis for conducting the operation.

X Q. 232. As you read the Jones patent the size of the mixer and

the size of the charges entering it are matters left to the skill or judgment of the engineer, are they not?

A. Certainly, within the limits by which he can procure a metal from the mixer that is suitable for conversion, uniform in character and changing only in a gradual way as to be in nowise objectionable to the converting department.

X Q. 233. Do you think it was sufficient to enable the steel engineer to determine the relative sizes of the mixer and the charges entering it to tell him that successive charges were to be combined in the vessel to give a uniform quality to the metal, without stating definitely the size or frequency of the charges?

847 A. I do not see from the description of the method, as set forth in the patent, any reason why any steel-works engineer could not properly apportion a mixer and the charges thereto, given a converting mill of a certain capacity in tonnage and blowing heats of a certain size, from careful analyses of the part of the casts from the blast furnaces, and understanding the furnace equipment and the character of the material for producing iron that was at his disposal and the quantity the furnace would produce—he could by a very simple calculation determine what amount of metal should be retained in the mixer, and what additions should be made thereto in order to obtain a product therefrom to procure a metal that was sufficiently uniform in quality to meet the exacting conditions of the steel works.

X Q. 234. Am I right in assuming that if the engineer of a certain works is told to mix the blast-furnace charges in a vessel to maintain a proper average metal, his skill should enable him to determine the size of the vessel, and the size and frequency of the ingoing charges for the particular works in question?

A. I do not consider that he would have any great difficulty in arriving at data that would give him the best results in the best way.

X Q. 235. Under good blast-furnace practice, what is the average variation in the percentage of silicon, within what limits should it ordinar-y come?

A. In the same furnace, I do not think, under the conditions of your question, in the best practice as I know it, that the variations would exceed 1 per cent., except in exceptional cases, although the variation may be as much as 2 per cent. in one furnace than in another.

X Q. 236. In converter charges, how near should the silicon in one charge run to that in the next, in order to give the blower a reasonable guide for the proper blowing of the second charge?

848 A. I cannot state definitely, as at our works we do not analyze every charge, but every alternate charge, and the silicon variation, as a rule, in alternate charges, varies from, I should say on the average, from .1 to .2 of 1 per cent., and very often not as much as this. We find that the blower can follow the steel under these conditions. Sometimes we find that the variation, as shown by the analyses, in exceptional cases is more than this, but as the work by the chemist is done rapidly, and there is no time to

duplicate the results, the associated data show that such results are undoubtedly an analytical error. Very often, for considerable periods, the variation is about .1 of 1 per cent., and my recollection now is, from observing these reports daily, that the variation is close to .1 of 1 per cent. and may possibly be below. If necessary, I can present absolute data from recent work.

X Q. 237. Assume that a converter charge contained twice as much silicon as another, would the blowing of the first charge be a reasonable guide to the blowing of the second?

A. I cannot conceive of any way in which it could be a guide.

X Q. 238. Assume that a converter charge contained 75 per cent. more silicon than another, would the blowing of the first be a reasonable or a reliable guide for the blowing of the second?

A. I do not consider that it would.

X Q. 239. Assuming that a converter charge contains 50 per cent. more silicon than another, would the blowing of the first be reasonable or proper guide to the blowing of the second?

A. Assuming that the first heat contained 1 per cent. of silicon, and the second 1½ per cent., the conditions that would have to be met by the blower would not be as radical as if the difference were
100 per cent., and to that extent would be more of an indi-
849 cation, but the indication becomes more strong the closer successive heats approach each other. For a good practice we would want them much closer than a difference of 50 per cent. The limit that we aim to get is about .1 of 1 per cent., or under.

Adjourned to meet May 4, 1897, at 10.30 a. m.

PITTSBURG, *May* 4, 1897.

Met pursuant to adjournment.

Present, as before.

Cross-examination of Mr. GAYLEY resumed:

X Q. 240. In considering the apparatus of the Deighton English patent, what capacity did you assume for the furnaces, the mixer *m* and the converters?

A. I made no assumption.

X Q. 241. With your knowledge of the art as it existed in 1873, what would be a fair assumption as to the size of the converters and the furnaces illustrated and described in the Deighton patent?

A. I presume the capacity of the converters would be about 5 tons, and the capacity of the blast furnaces in English practice about 50 tons a day.

X Q. 242. Under ordinary conditions, about how often would the Deighton blast furnaces have been tapped?

A. Having had practical experience in operating at one time a furnace of such capacity, we made three taps a day of 8 hours intervals. Afterwards we changed that to casting every 6 hours. I do not know in practical experience of a furnace making that tonnage being tapped in less time than 6 hours.

X Q. 243. Assuming the Deighton furnaces and converters to be of the sizes stated by you, what would you consider a fair estimate

of the capacity of the intermediate mixer vessel *m*, as shown and described in the Deighton patent?

850 A. As I recollect Mr. Deighton's drawing and description, he represents two furnaces connected with the mixer or reservoir, and with spouts leading to two others, and states, I believe, that it can be operated with two or four furnaces. If he were using two furnaces, he would make the receiver of such capacity as would hold two casts. If using four furnaces, he would make it to hold four casts.

X Q. 244. How many taps of the blast furnaces does the Jones vessel at Edgar Thomson hold?

A. The capacity of the mixers at the Edgar Thomson is 200 tons. We have two mixers, each of 100 tons capacity, and the alternate ladles are poured into the two mixers at the same time, and the metal withdrawn is taken half from one mixer and half from the other. I state this to explain that we in practice consider in the method of operation that we have a 200-ton mixer. Taking the ordinary taps from our blast furnaces three taps would fill these mixers.

X Q. 245. Then each mixing vessel at Edgar Thomson will hold less than two furnace taps?

A. At the present time, that is the fact.

X Q. 246. Has it ever been otherwise at Edgar Thomson?

A. It has. When the mixers was installed, one mixer would hold from two to two and a half furnace taps. The product of the blast furnace has increased materially in the last ten years.

X Q. 247. Each mixing vessel at Edgar Thomson is now smaller in proportion to the blast furnaces than the vessel of Deighton, in relation to his blast furnaces, is it not?

A. As one and a half taps from a blast furnace at the present time will fill one of our mixers, it therefore will not hold as many taps as what I assume is the capacity in taps of the Deighton vessel.

X Q. 248. At that time of the Deighton patent, what was the average time required for the blowing of a five-ton converter charge?

851 A. I do not know; probably 15 to 20 minutes, as they used higher silicon metal then than they do now.

X Q. 249. At Edgar Thomson previous to the introduction of the Jones mixer, when working direct metal, was it not your custom to tap the blast furnaces in rotation or succession?

A. That was the practice.

X Q. 250. And it is still the practice at Edgar Thomson to tap the blast furnaces in rotation at approximately regular intervals?

A. That is correct.

X Q. 251. It has been the usual or general practice, has it not, in all works using direct blast-furnace metal to tap the furnaces in rotation to secure a practically constant supply of metal?

A. That is the practice.

X Q. 252. How far back does that practice extend?

A. I only know it to extend as far back as the beginning of the direct-metal process.

X Q. 253. At the Edgar Thomson works, you have no means of heating the mixing vessels during the withdrawal of the final charges, have you?

A. No satisfactory way. Our method of heating the mixer is by inserting a burner in the pouring spout. To do so when we are emptying the mixer would necessitate the removal at the pouring of every heat, and it would be considered a great inconvenience.

X Q. 254. In building your new mixer at the Duquesne works you have departed from the shape of vessel shown in the Jones patent, and adopted a semicylindrical vessel, having a gas pipe for heating purposes?

A. We, in constructing our Duquesne mixer, adopted the shape we installed as a more convenient shape and giving more capacity in a small bulk, but do not attach any importance to the shape of the vessel. We have likewise introduced a gas pipe on the
852 side, and when put there it was for the purpose of heating the empty mixer at the beginning of the week before the introduction of the new charges, and particularly for the purpose of trying the experiment of retaining a considerable quantity of metal in the mixer from Saturday night until Sunday night, and this was necessary to keep the metal from sculling. It was not constructed with a gas-pipe attachment for the purpose of using auxiliary heating during the week.

X Q. 255. I will again ask you whether the new mixer you have installed at Duquesne is not of a semicylindrical form?

A. That is the shape of it.

X Q. 256. Your new Duquesne mixer is almost identical in form, is it not, with that installed by the Maryland Steel Co. in 1890 or 1891?

A. It has been so long since I have seen the Maryland Steel Co. mixer that I cannot recall definitely its shape. My general impression is that the body of the mixer was semicylindrical, but the spouts were so constructed as to give it more the appearance of a turtle shell. The Duquesne mixer, as I have stated, is semicylindrical in cross-section. The sides are shaped in the other section to give it, as far as possible in construction, a hemispherical shape, which, as I recall, is not the shape of the Maryland mixer.

X Q. 257. But the fact remains that your new Duquesne mixer, like the Sparrows Point mixer of 1890 or 1891, has a semicylindrical body, mounted on rollers so as to turn or roll about its axis with a discharge spout on one side through which part or all of the metal may be discharged by revolving the vessel?

A. That is correct, I believe.

X Q. 258. Am I correct in understanding you, as a practical steel worker, to mean that a special form of mixing vessel is necessary to carry out the Jones process?

A. I do not consider that a special form of apparatus is essential

to the carrying out of the Jones process, although, for special
853 reasons, a certain general type of apparatus would commend itself to any practical man as the most suitable way to carry it on.

X Q. 259. Do you consider it vital to the carrying out of the Jones process that the mixing vessel shall have a lid or cover?

A. The Jones method cannot be conducted in a vessel that is not provided with a cover.

X Q. 260. Will you state all the functions of the cover as used with a Jones mixing vessel?

A. I do not know that I can state all. I will enumerate some. It prevents radiation of heat and making successive withdrawals ununiform in temperature. It prevents oxidation of silicon to a greater or less extent. It prevents the vessel from being sculled over, which would be the case without a cover, and which would in turn prevent its operation being a continuous one, which is the method of the Jones mixer. I, however, do not consider that the cover being on a vessel is any indication that the Jones method is used. On the other hand, its absence is conclusive that it is not used.

X Q. 261. The Jones patent says my invention may be practiced "by merely receiving in a charging ladle a number of small portions of metal taken from several ladles or receiving vessels containing crude metal obtained at different times or from different furnaces, the mixing being performed merely by the act of pouring into the charging ladle, and other like means may be employed." Do you find in this description anything which indicates the use of a cover or a closed vessel?

A. I would take this to mean that the metal obtained from different furnaces, obtained at different times, was poured into one or more receiving vessels, and that a charging ladle should draw an aliquot part from each receiving vessel, and in this way, if each receiving vessel was different, there would be a mixture in
854 the ladle; if they were the same the mixing would be that simply of three like portions. In such practice the method would not be to pour a cast from one furnace into one receiving vessel and another into another, but that one cast would be distributed to all of the receiving vessels. This is practically and substantially the method that we use at the Edgar Thomson works in which we have two receiving vessels, and from which we pour an aliquot part from each receiving vessel or mixer, as it is called, into the ladle, in order to make the charge. Such receiving vessels are filled with alternate ladles of iron from the blast furnaces, and such receiving vessels or mixers must be covered in order to make the operation a continuous one. I think, therefore, that this statement refers to the advantages of installing more than one mixing or receiving vessel, instead of one larger one, in order that the operation may not be discontinued when it is necessary to make repairs.

X Q. 262. Is your last answer based upon the Jones patent, lines 82 to 91, page 1, which I quoted in X Q. 261?

A. My reply is based on the operation of the Jones mixer at our

works, and from my knowledge thereof as practiced and how the conduct of such a method of operation as you have described could be carried out in a practical way.

X Q. 263. Do you mean to say that as an engineer, reading the Jones patent, lines 82–91, you would understand, without special instruction from the patent, that the vessels used would have to be covered vessels?

A. Not having any experience in the interpretation of patent specifications, it would appeal to me as a way of performing such operation as described from the standpoint of a practical man, having had considerable experience in the handling of large quantities of molten metal.

X Q. 264. Patents are by law addressed to persons skilled in the art. I therefore ask you, as an experienced engineer in metallurgy, whether on reading the Jones patent, lines 82–91, you would
855 understand, without other instruction, that covers would be necessary on the vessels to prevent loss of heat, or for any other reason?

(Objected to, for the reason that the question is limited to specified number of lines, and excludes the remaining portions of the specification of the patent, and it is therefore incompetent.)

(The attention of the court is directed to the fact that the language quoted is the entire description contained in the patent of one form of apparatus for carrying out the patented invention.)

A. As you state that patents are addressed to persons skilled in the art, I would conclude that it is fair to assume that all the minutiæ of the operations are not necessary to be explained, and therefore would be compelled to draw upon my practical experience in considering these lines quoted, without reference to anything else in the specification, that these ladles or receiving vessels should be covered, inasmuch as the scheme is to supply Bessemer converters, which operation must be continuous, and it could not be performed in a vessel or ladle that was uncovered; and, moreover, as showing the correctness of such conclusion to a practical man, I would state that at one time we transported our molten metal in ladles across the river to the Homestead steel works, and as the metal was to be retained in these ladles longer than the ordinary time required in our mixer practice, the first step we took in such operation was to place a substantial cover on them in order that they might retain their heat and prevent sculling.

X Q. 265. Covered or closed vessels lined with refractory material and adapted to contain molten metal, were known in the art in different forms, were they not, prior to 1888?

A. Yes, there were used puddling furnaces for the purpose of melting down and puddling iron, and open-hearth furnaces
856 which were lined with refractory material and provided with a cover for the purpose of controlling and directing the flow of gas necessary for the operation.

X Q. 266. Prior to 1888, was it not a common practice to provide

ladles or other vessels for holding molten metal with lids or covers to prevent the loss of heat?

A. It certainly was not the common practice. I cannot at this moment recall a single case wherein I have seen a ladle provided with a cover. I may have seen a case, but at the present moment it is impossible to recall any.

X Q. 267. Have you at Edgar Thomson, under the Jones process, performed the mixing merely by the act of pouring the metal into the charging ladle?

A. The question is not clear to me; it does not state what metal is referred to.

X Q. 268. Have you at the Edgar Thomson works taken crude metal obtained at different times or from different furnaces and mixed this metal to obtain a suitable converter charge by simply pouring the metal into a charging ladle?

A. As I understand the question, this considers the tapping of the metal from a blast furnace into ladles and then pouring portions of these ladles into a charging ladle, in order to obtain a mixture. I know of no instance that this has been done, nor do I recall of any contrivance around our works whereby we could have performed such an operation.

X Q. 269. Can the Jones mixer be fairly described as a vessel having side trunnions, a close top, a filling opening, and a pouring spout?

(Objected to as indefinite and incompetent.)

A. I would not so describe it, nor limit it to any form of construction.

X Q. 270. What characteristics or features, other than those named above, are requisite for a mixer?

(Objected to as containing an inference at variance with the preceding answer of the witness.)

857 A. I do not know what other features might be requisite, except what I have seen and observed in the practice of it, namely, that it is not only a vessel having these mechanical adjuncts, irrespective of size and capacity, but must be a vessel of such size and capacity as shall be suited to obtain the results from the same kind of material as are obtained by the Jones method as practised.

X Q. 271. Why did you install a second mixing vessel at Edgar Thomson?

A. For very excellent reasons. When we first began to use the mixer we had some difficulties to contend with as are incident to the development of a new process, and these delays allowed the mixer to scull up for us shortly after starting. We did not have the appliances erected at that time for cleaning the mixer rapidly, and it was decided that rather than have the process interrupted and lose the benefits that we obtained from the use of the mixer, our best policy would be to construct a second one, so that under no conditions would we have to send the metal to the steel works without equalizing its irregularities through a mixer.

X Q. 272. At Edgar Thomson each ingoing charge of blast-furnace metal is equal to about one-eighth of the capacity of the mixer is it not?

A. That is not quite correct. The nominal capacity of the mixer is 100 tons and the ladles are 10 tons, which would make it one-tenth, although the mixer skulls up somewhat to about 80 tons capacity, yet the ladles likewise skull, and I presume proportionately, so that under some conditions it may be one-eighth, and again it may be one-tenth. This as relates to one mixer.

X Q. 273. What proportion of the contents of the mixer at Edgar Thomson is usually withdrawn at one time?

A. As stated before, it is our custom to fill the charging ladle half from one mixer and half from the other. The average weight of metal in the charging ladle as taken to the steel works is 14
858 tons. This would mean a withdrawal of 7 tons from the mixer, and as the mixer will hold about 80 tons, the withdrawal would be approximately one-eleventh of the amount originally obtained.

X Q. 274. Is it your practice at Edgar Thomson to hold back the ladles of furnace metal when there is room in the mixers for the additional metal?

A. Such is not our practice. The aim is to get the metal into the mixer as quickly as possible after being cast and as occasion presents itself for pouring it in, in order to prevent the radiation of heat and the sculling of the ladle, and also to keep as large a body in the mixer as we can.

X Q. 275. Why do you employ ladles to carry the molten metal from the blast furnaces to the mixer?

A. I don't know how else we could get it there from our seven blast furnaces that generally run on Bessemer metal, and as we were using the ladles to transport the metal to the steel works when we were running direct, the obvious way would be to employ them for taking the metal to the mixer. The closest furnace to the mixer was approximately 600 feet, and the farthest one a little more than a quarter of a mile.

X Q. 276. Assuming that differing portions of furnace metal are mixed in a receiving vessel, and that to this mixed metal, after being drawn out, 50 to 60 per cent. of molten cupola metal is added to complete a converter charge. Would you consider this coming within the Jones process as you read it in the patent?

A. Assuming the data as stated, and that the portions of furnace metal were irregular in composition, and were mixed with other metal in a receiving vessel in order to make uniform the irregularities, such metal withdrawn from time to time would be treated in the manner prescribed by the Jones method, irrespective of whether it received additions of cupola metal or other metal.

859 X Q. 277. Then, you think that the Jones method may be practiced, although the converter charges may consist largely of cupola metal, do you?

(Objected to as indefinite.)

A. The Jones method, as I know it in practice, consists in treating molten metal from the blast furnace which is irregular in composition, and provides means for overcoming these irregularities, and to furnish a metal practically uniform in composition for use in Bessemer converters; and having so furnished such metal, it has performed the office or function of the Jones mixer, and it does not insist that such metal shall be poured into the Bessemer converter without subsequent doctoring, and I presume that if a manager chose to pour in cupola metal or spiegel or manganiferous pig, or any of the previous metals, there is nothing, as far as I know with respect to the Jones method, that will prevent it.

X Q. 278. Am I correct in understanding you to mean that the Jones method is really completed or ended when the mixed metal is drawn from the mixer?

A. The Jones method, as practiced, is to prepare the ununiform products of a blast furnace in a certain way by which they can be made uniform for use for further refining. That, as I understand it, is the function of the mixer. The metal is eminently suited in itself for conversion into steel, and will fulfill all the requirements, and as far as the metal that is used in a Bessemer converter has been treated that way, it fulfills them. The Jones mixer method, as I understand it, has nothing whatever to do with the practice of pouring it directly into the converter, or whether, as a matter of convenience to the works, the same ladle may be used for conveying as a part of the charge metal which had been remelted in the cupola as the result of certain commercial reasons.

860 X Q. 279. Am I not right, then, in understanding that the Jones process ends when the mixed metal is taken from his receiver?

A. The Jones mixer method, as I understand it, ends in preparing a metal from blast-furnace casts or portions thereof of such uniformity and composition that any variations in composition can be readily corrected by the usual means in the converting mill, and providing the same regularly thereto as a continuous operation.

X Q. 280. I will ask you to say, as briefly as possible, whether the Jones method as you read it in the patent includes as part of the method the delivery of the metal from the mixer to the converter for the converting operation?

A. The Jones method provides suitable material for the converting operation. I do not know where the patent expected the metal to be delivered. It might be delivered to a converter or to an open-hearth furnace, or for any refining process. I only know that from practical experience we prepared the metal, sent it to the converting mill, and that ended the operation; but I do not know that the method requires the delivery to any particular spot after being withdrawn from the charging ladle.

X Q. 281. To the extent to which the cupola metal may be used in the converter, the advantage of the Jones method is lost, is it not?

(Objected to, as the word "lost" is indefinite.)

A. Assuming that we use in the charging ladle 50 per cent. mixer metal and 50 per cent. cupola metal, it would be the combination of two metals each of uniform quality, and I am not prepared to say that there would be either a gain or loss in advantage of either. The question is not quite clear to me as to what is meant by the word "advantage."

X Q. 282. One of the principal advantages of using the Jones method is that you avoid the expense and trouble of remelting cupola iron, is it not?

861 A. That is so.

X Q. 283. And to the extent to which you use cupola iron in the converter, you lose the money advantage of the Jones method?

A. That is correct.

Adjourned to meet May 5, 1897, at 10.30 a. m.

PITTSBURG, *June* 2, 1897.

Met pursuant to agreement of counsel.

Present, as before.

Cross-examination of Mr. GAYLEY resumed:

X Q. 284. In using mixer metal, in the ordinary way of working, has the blower any positive means of knowing whether the converter charge following the one just blown will be of higher or of lower silicon?

A. None absolutely, although to a certain extent he has in this way that the silicon in our mixer metal has practically a high and a low register. If it is on the high register he is sure that the next succeeding heat, although varying very little, would have a tendency to decrease; whereas, if on the low register, the tendency would be to increase. This is occasioned by the fact that they aim to obtain about a normal percentage of silicon, and if the furnaces have a tendency to make high-silicon iron, the furnace superintendent reduces it as quickly as possible, and increases the silicon when it is low. Between those points the variation takes place by such slow or gradual changes, that although he may not know which way the change is going, ordinarily it is so small that it does not interfere with his work.

X Q. 285. If he does not know which way the change is going, whether to higher silicon or to lower silicon, then in the practical operation he must anticipate double the amount of variation which actually occurs, must he not?

862 A. In my former testimony, I stated that the variation was about .1 of 1 per cent. or under, and it is generally under .1 of 1 per cent. This is expressed in alternate heats, so that the successive heats would only vary .05 of 1 per cent. or less at the present time, and for which change in practical working he would make no provision, but would treat his heat in the same way until the change was clearly marked.

X Q. 286. I believe your custom at Edgar Thomson is to fill the two ladles at one time, pouring half from each mixer into each ladle

and to take analysis of the metal in one ladle. Is not this the custom?

A. That is correct. This makes each alternate heat to be analyzed.

X Q. 287. And it makes those two ladlesful so drawn of practically the same silicon, does it not?

A. They would practically be of the same silicon content.

X Q. 288. And it is an advantage to the blower to have the two converter charges of practically the same silicon content, rather than have variations between each converter charge, is it not?

A. Theoretically, yes, because if he made a mistake on one, he could correct it on the other, but practically the variations between those two ladles and the next two are so small that it makes no difference in the operation of a mill; and while it is the rule to take up two ladles at one time, very often only one is filled and sent to the converter mill.

X Q. 289. Would it not be advantageous to the blower to have several converter charges of the same silicon before any variation in silicon occurs, rather than to have possible variations of silicon for every one or two converter charges?

A. I know from my practical experience that it would be a positive disadvantage, because while he might have several heats of precisely or practically the same composition, yet when the
863 change came it might be so radical as to cause the spoiling of the heat before the converterman could adjust himself to the next change. I would consider this method of furnishing heats to a converting mill identical with what we often practiced in our direct process, whereby we would take a cast of iron, fill the ladles about a third full on the first round, then add another third, and then finally completing, which was done by diverting in the furnace runner the iron from one ladle to another, making practically four or five ladles of the same practical composition, but these several ladles would differ so radically from the next several, that we could not control the process. The advantage of a change, when a slight one, is much preferable, as it maintains a continuity in the quality of the metal from practically one heat to another.

X Q. 290. I intended my last question to refer to mixer metal with variations such as the analyses you have produced show to occur in the mixer metal at Edgar Thomson works. Under such circumstances would it not be advantageous to the blower to have several converter charges of the same silicon before any variation of silicon occurs, rather than to have possible variation of silicon for every one or two converter charges?

A. My previous answer would apply equally well to mixer metal as to direct metal. To explain further, I would say that ideal charges for a Bessemer converter are those in which there is no change in composition from one charge to another. The next condition is that in which the changes are made gradually, high silicon running into low silicon, and *vice versa*, by gradation, and again, when the changes from high to low or from low to high are

made abruptly, it is not desirable and cannot be followed by the converterman.

X Q. 291. You have not answered my question. Please read it over and answer it.

A. Answering further I must assume that while the several converter charges have the same silicon, the next several
864 charges show a variation of silicon from the preceding which may or may not be radical, and from the conditions of the question I must assume that there is no connection between these series of several converter charges. I would therefore state positively that the practice of having a gradual change from heat to heat is in every way most desirable.

X Q. 292. I must restate my question, as in your last answer you have added matters not intended to be included in it. If you have a group of several converter charges of mixer metal, followed by other groups of several such charges, and the variation between these groups is within the range which the analyses you have produced show to occur between successive charges in the mixer metal at the Edgar Thomson works, would this not be more advantageous to the blower than to have possible variations of silicon for every one or two converter charges?

(The question is objected to as being indefinite, it not being stated in what manner or under what conditions these groups are to be formed.)

A. As I understand your question we might have, say a batch of eight or ten successive heats that were of identical composition, and then the next batch of eight or ten heats might vary from the first, say by less than 1 of 1 per cent. There would be practically no difference, as far as practice is concerned, than if the variation had been distributed throughout the whole number of successive heats equally. The variation between the two batches would be so small as to enable the operation to be practically a continuous one in either case, although I know of no way by which batches of a composition so remarkable in their resemblance to each other could be prepared from a blast furnace or mixer.

X Q. 293. Why do they at the Edgar Thomson works weigh the converter charge twice, once at the mixer and once at the converter department?

A. For very good practical reasons. When they started the direct process, the metal was all weighed at the converter mill, and
865 the furnace department thought that their tonnage of molten metal showed less than they estimated it should be, so the scales were introduced at the blast furnaces in order to have a check and to obtain some definite knowledge as to furnace practice. These two weighings showed clearly the amount of waste or scrap that was produced by the direct-metal process.

After the installation of the mixer, the scales were put in front of them for two reasons, one of which was to show the amount of scrap made by the operation, and another one was to send as near the exact weights as was wanted at the converting mill. For a while

they abandoned weighing the mixer ladles at the mill, but the cards that went up with the ladle showed the weights got misplaced occasionally, so that the steel works began again to weigh all the metal that came from the mixer, and this was advantageous for two reasons, one of which was to show the blower how much metal he had in his vessel, which assisted somewhat in the pouring of the steel, and, again, it was the basis on which the converting mill paid for the molten metal it received.

X Q. 294. Do you know whether there are weighing scales in front of the converters at the Cambria works?

A. There are.

X Q. 295. How close to the large metal reservoir in the Cambria works are the converters?

A. I should say about fifty feet to the nearest converter, and the others extend in line.

X Q. 296. It is a fact, is it not, that at the Edgar Thomson works, you melt pig metal in cupolas, and put this molten cupola metal through the mixer with the blast-furnace metal?

A. That is but a partial statement of our operation. The cupolas you refer to are located close to the mixer, so located because it was the only convenient ground we had to place them on. We had before their construction an accumulation of irregular pieces
866 of converting-mill scrap, and we concluded it would be better to remelt this scrap in the cupola and send it to the converting mill, rather than go to the expense of breaking it up, as it was exceedingly tough. On starting these cupolas, the charge was principally scrap, and we simply added enough high-silicon metal in order to make the metal tapped from the cupolas fluid enough to prevent chilling. The nearness of the cupolas to the mixer suggested on starting that we melt this iron in the cheapest way possible and use as little fuel as possible, and that we could overcome the disadvantage of the high sulphur in this cupola metal by pouring it in as tapped in small quantities into the mixer, which contained low sulphur metal. These cupolas were known around the Edgar Thomson works, and designated as scrap-melting cupolas.

X Q. 297. In so doing, did you practice the method of the Jones patent?

A. I did not consider that it was the Jones method, inasmuch as that calls for the treatment of molten metal procured from a blast furnace. I referred to the use of this melted steel scrap.

X Q. 298. Please read the second claim of the Jones patent, and state whether, considering this metal so melted in the cupolas and passed through the mixer with the blast-furnace metal as molten metal, any step of the method of that claim was absent, and if so, what step?

(Objected to as indefinite, and as incompetent.)

A. It was not the Jones process, because it did not treat molten metal obtained directly from a smelting furnace.

X Q. 299. Where, in the second claim of the Jones patent, do you

find any reference to molten metal obtained directly from the smelting furnace?

(Objected to as incompetent, and not proper cross-examination.)

A. It is very clearly expressed in the Jones patent. For instance, on page 2, line 26, he speaks of molten metal employed in
867 charging the mixer. In line 103, he speaks of the mixer holding a large quantity of molten metal. In line 115, same page, he mentions repeated fresh charges of molten metal. On page 3, line 2, he mentions metal supplied to the converter. Likewise on page 2, line 74, he mentions the mixer in position "ready to receive a charge of metal," showing that the terms "metal" and "molten metal" were used interchangeably. Now, by referring to page 1, lines 60–65, he specifically states from where the metal or molten metal was derived, which was from a smelting furnace, which is ordinarily called a blast furnace, and further as showing that molten metal meant to the inventor only the molten product from the blast furnace, I herewith put in evidence a blank form used at our Edgar Thomson works ever since the introduction of the direct-metal process, in which the product of the blast furnace is designated as being of two kinds, molten metal and pig iron, the molten meaning the metal taken away hot, the pig iron the metal which was run into pigs and allowed to cool.

(Answer is objected to by defendant's counsel as wholly irresponsive, and the part thereof referring to the blank form produced by the witness and injected into the record, is objected to as immaterial and irrelevant.)

(The examiner is requested by complainant's counsel to make the blank form offered by the witness a part of his deposition by marking the same "Complainant's Exhibit Gayley Blank Form.")

(The exhibit is objected to by defendant's counsel as irrelevant and immaterial.)

X Q. 300. Question 299 repeated.

(Objection continued.)

A. I may have misunderstood your question as referring to the whole patent, but as the molten metal mentioned in the second claim is the same term that is used throughout the whole patent, and which was obtained from a smelting furnace, it is quite
868 clear to my mind from what I have previously stated that the molten metal herein mentioned refers only to that from a smelting furnace. Moreover, the use of the terms "portions of molten metal ununiform in their metallic constituents, silicon and sulphur," would naturally lead a practical man to conclude that it was blast-furnace metal, as such metal is altogether ununiform in successive portions.

X Q. 301. Can you, as a person skilled in this art, explain why the first claim of the patent refers to iron directly from the smelting furnace, which would include the matter referred to in your last answer, while the second claim employs the broad term

"molten metal," which would include molten cupola metal or other forms of molten metal, as well as that from a smelting furnace?

(Objection continued.)

A. I note in the first claim that it refers to iron in the liquid state as subsequently explained taken directly from the smelting furnace, and in the second claim the term "molten metal" is used, which is apparently a broader term, but under our method of operations at the Edgar Thomson works it was not so in reality, for we spoke of this liquid metal from the smelting furnace under different shop terms, as direct metal, hot metal and molten metal, the latter being the one used exclusively in our accounts and records of the works; but no matter when any of these terms were used, since 1882 at the Edgar Thomson works they referred to the metal taken directly from the smelting furnace in a liquid state.

X Q. 302. I ask you nothing about what you did at the Edgar Thomson works, but as a person skilled in the art, reading that patent, I want to know how you can explain the distinction between the term "iron directly from the smelting furnace" in the first claim, and the term "molten metal" of the second claim, otherwise than making the term "molten metal" have its natural
869 broad meaning as including other molten metals than that taken directly from a smelting furnace.

(The former objections are continued, for the reason that if the question is proper at all, it can only be proper in connection with the practical operation of the method as known to the witness.)

A. From my practical knowledge of the art, and reading that patent, I could only conclude that molten metal referred to metal obtained directly from a smelting furnace, and in the practice of the art of manufacturing iron and steel, molten metal has no broad meaning, but is a specific term, and just as specific as other terms which we use. For instance, if it is liquid metal from a Bessemer converter, we call it Bessemer steel; if from an open-hearth furnace, we call it open-hearth steel; if from a cupola, we call it cupola metal; and if from a blast furnace, we call it molten metal; thus giving to it a specific name well known and well understood around all blast furnaces and steel works.

X Q. 303. In the regular practice at Edgar Thomson in 1887 and 1888, about how often was a charge converted in the converter?

A. About five or six heats in an hour.

X Q. 304. What has been your experience in the use of direct metal at Edgar Thomson, as to the skulling of the metal; that is in which will the greatest amount of skulling take place in proportion to the metal held therein,—in the metal mixer, or in the carrying ladles taking the metal either to the mixer or from it to the converting mill?

A. In the carrying ladles, they being uncovered and exposed to

the air would naturally skull the most and skull rapidly. There would be more points of radiation per unit of metal.

X Q. 305. I believe that at the Edgar Thomson works a record is kept showing the number of blows in the converter mill the
870 time that the ingots are held in the heating furnaces and the percentage of seconds with certain other records. Is this the case?

A. The mill keeps full records of the different elements of practice. At times the length of time required for heating ingots has been kept, but that feature has not been a constant practice.

X Q. 306. Will you please produce the record of the complainant company which shows the number and character of blows, the time that the ingots were held in the heating furnaces and percentage of seconds at the Edgar Thomson works for the months of July and August, 1893?

A. I will endeavor to procure them with the consent of the president of the company.

X Q. 307. Will you also please produce from the records of the company the records showing the different blast furnaces from which the analyses referred to in your answer 9 were taken? That is, showing to which furnaces the analyses of silicon and sulphur given in that answer referred.

A. I will endeavor to procure them, with the consent of the president of the company.

X Q. 308. Please also produce from the records of the complainant company the yearly tonnage of Bessemer steel produced at the Duquesne and Homestead works of the complainant company since 1887?

A. I will endeavor to procure them, with the consent of the president of the company.

X Q. 309. You referred to the Duquesne mixer as a semicylindrical vessel and also gave the same general description to the reservoir at the Maryland steel works. Do you remember the general construction of the reservoir of the Illinois Steel Co. at their South Chicago mill?

A. I think I do. My recollection is that it was cylindrical in cross-section, although I have not seen it for a number of years.

871 X Q. 310. I show you a blue print said to be of that reservoir; will you please examine it and state whether it is substantially correct according to your recollection?

A. It is.

(The blue print referred to by the witness is offered in evidence and marked "Defendant's Exhibit South Chicago Reservoir.")

(Objected to as irrelevant.)

X Q. 311. What do you understand to be the meaning of the reservoir for liquids?

A. It has, I believe, ordinarily been considered such as water reservoirs for holding a supply for the purposes of distribution.

With regard to metals I have quite recently heard it used and understand it to be used as a new name to designate a metal mixer.

X Q. 312. Do you consider the term "reservoir" used in connection with metals to be synonomous with "metal mixer"?

(Objected to as irrelevant.)

A. I would not consider it so and am at a loss to understand why the term should ever have been applied to a mixer, the purposes being quite different.

X Q. 313. I asked the last question because you had apparently given it that meaning in your preceding answer. Whether it is a reservoir for water or for metal, the term "reservoir" would naturally include a receptacle for holding a supply of the liquid, would it not?

A. I understand by "reservoir" that its common use is as a receptacle for the purposes of distribution only.

X Q. 314. In the ordinary use of a reservoir, liquid is fed thereto to keep up the supply, and withdrawn therefrom as needed; is this not correct?

A. That is correct, but the manner of feeding thereto and withdrawing therefrom, and the size of the reservoir, have much to do with the purposes for which it is used.

872 X Q. 315. In the ordinary or normal use of a reservoir, the liquid fed thereto to keep up the supply is added to that which remains in the reservoir at that time, is it not?

A. That is correct.

X Q. 316. And the liquid so added necessarily mixes or intermingles with that which is in the reservoir, does it not?

A. Nothing would prevent it.

X Q. 317. And the liquid subsequently withdrawn from the reservoir would naturally be a composite or average of the different liquids fed thereto, provided there was any difference in the constituent parts of the liquids, would it not?

(Objected to as indefinite.)

A. That does not follow. If the withdrawal would be made immediately after a quantity was charged, it would scarcely represent an accurate mixture of the mass, unless the element of time was given to allow for a proper commingling.

X Q. 318. Did you ever personally have charge of, or were you ever connected with a Bessemer works, in which all the metal used for conversion was melted in cupolas?

A. I have never had under my charge a Bessemer department operated by cupolas, although I have frequently seen and observed the practice at our other works, and am familiar with it.

X Q. 319. Have you ever personally known or seen the practice of filling a ladle or receptacle with molten metal and covering the same with coke or coal or charcoal dust, and pouring out part of that metal, leaving part in the vessel and filling it up again?

A. I cannot recall having seen such done; it would be considered exceedingly bad practice, because the metal used in replenishing

would splatter over the coke dust and chill rapidly, forming a skull.

873 We constantly at our works fill ladles with metal, cover them with coke dust, but invariably drain them when emptied, and then scrape the coke dust out by means of a rabble, in order to prevent them from skulling, which would happen if we left the coke dust in.

X Q. 320. It is a fact, is it not, that within the last year or so you visited the car-wheel foundry of the Pennsylvania railroad at Altoona, and saw it in operation?

A. I have.

X Q. 321. Did you not see there the ladle or reservoir into which the molten metal was tapped from the cupolas from time to time, and from which small ladlesfull of metal were withdrawn from time to time for casting the wheels?

A. I did.

X Q. 322. Did you not see that they had the molten metal in the ladle or reservoir covered with charcoal, coal or coke dust?

A. I cannot recall whether they covered the ladle with charcoal dust or not. I have seen foundries where the metal is used from a ladle which had not any carbon covering on it. I cannot state whether the one at Altoona had or not.

X Q. 323. Have you seen foundries in which the metal in the ladle was covered with carbon dust of some kind to hold the heat, and if so, where?

A. I saw a ladle at the Whitney foundry on which was a thin covering of charcoal, placed around the edges of the ladle, the whole surface not being covered, although at times it might have been.

X Q. 324. When you saw the Whitney foundry in operation, the molten metal was tapped from the cupolas from time to time into the ladle or reservoir, and small ladlesfull of this metal were drawn from the cupolas from time to time for casting into wheels. Was not this the practice?

A. When the cupolas were ready to tap, they were tapped at one time and the metal run into a ladle, from which small ladles

874 were filled for the purpose of casting car wheels.

X Q. 325. And when the cupolas were again ready to tap, the metal therefrom was tapped into the large ladle and mixed with that which remained therein. Was not this the fact?

A. The metal was run into the ladles, and as each successive tap was of practically identical composition with the preceding tap, it rather amounted to filling up the ladle with a charge of the same material as remained therein, the same as adding a quantity of water to another quantity, but in which there was no principle of mixing, as I understand it.

X Q. 326. How do you personally know that the metal which you saw tapped into the ladle at the Whitney works was "of practically identical composition with the preceding tap"?

A. Because I saw all the conditions fulfilled for the procuring of uniformity, as delicate as it appeared to me to be obtainable in practice. I inquired of Mr. Fought, their engineer, how he made

his mixture for charging the cupola, and he showed me a buggy placed on a pair of scales, and surrounding the scales were small piles of iron of different grades and a pile of old car wheels. The pieces of pig iron were broken very small in order to get an accurate weight. Mr. Fought explained to me, and I also observed it, that so many pounds of this metal and so many pounds of that metal were charged in, with the addition of so many pounds of old car wheels of their own manufacture, and that these were weighed with the utmost exactness and that they were taken to the top of the cupolas and the cupolas were charged alternately with these mixtures. Mr. Fought explained to me that their old car wheels were the most uniform material in their mixture, which would be confirming evidence that their practice was very uniform in producing uniform metals.

875 (So much of the answer as is hearsay is objected to for that reason.)

X Q. 327. Have you any personal knowledge as to the degree of uniformity required in car-wheel castings?

A. I have never been connected with a car-wheel works, but I know that the practice for making them, and the requirements for service on the track are such that it is necessary that each wheel should be like the others, not only made during the same day, but the same throughout the month and throughout the year. This is very important as the car-wheel maker who risks a change in the composition of his wheels risks his reputation and his trade.

Adjourned to meet June 3, 1897, at 10.30 a. m.

PITTSBURG, *June* 3, 1897.

Met pursuant to adjournment.
Present, as before.

Cross-examination of Mr. GAYLEY resumed:

X Q. 328. In answer 289, you speak of a practice of tapping iron from several furnaces into several ladles in rotation. At what date was this practice, and where?

A. This practice I referred to in answer to Q. 289 was at the Edgar Thomson works from 1885 to 1887, approximately.

X Q. 329. Can you refer me to any place in the art or in the literature of the art in which "molten metal" is defined or referred to as being specifically "blast-furnace" metal? I mean elsewhere than in the Jones patent.

A. I cannot at this moment recall anything in the literature of the art, specifically so stating, but as to a place in the art which I take to understand as meaning where the art is practiced, I have heard hot metal from the furnaces designated by the term "molten metal," and know it to be used as a shop term in the art; and all people connected with the practical manufacture of iron and steel are accustomed to use shop terms well understood by each
876 other, which may not be found in the literature of the art. Moreover, I do not think it possible for any employee of an

iron or steel works to take any other meaning from the term "molten metal" than that which was obtained from smelting furnaces. If cupola metal had intended to be described, it would have been so called.

X Q. 330. Then if a printed publication referred to the mixing of molten metal, I am safe in assuming, am I, that it referred to blast-furnace metal, and it would be so understood by those skilled in the art of iron manufacture?

(Objected to as indefinite and as containing unwarranted assumptions.)

A. If the term "molten metal" was used, and it further stated that this metal was to be subsequently refined, I think without doubt it would be taken as a specific term indicating blast-furnace metal.

X Q. 331. Would this also be true as to the expression "molten iron"?

A. From all my experience I would answer the same as before.

X Q. 332. Why did you practice the mixture of hot and cold blast-furnace metal in the ladle, as stated in your answer 167, and Julian Kennedy's answer 39?

A. We mixed the hot and cold iron together because they represented in each case extremes from what we wanted for good converter practice, and the purpose was to obtain a mean between these two extremes, and also to make serviceable a cast of iron which would otherwise have been condemned and would have had to be remelted in the blast furnace.

X Q. 333. What was the date of this practice at Edgar Thomson?

A. We did this from 1885 to 1887.

X Q. 334. Why do you tap the blast furnaces at Edgar Thomson in rotation?

877 A. In order to provide metal for successive replenishing of the mixer, to provide for the withdrawals.

X Q. 335. Would it have been practicable at Edgar Thomson, or at defendant's works, to have tapped the furnaces at one time and retain the metal in molten condition until demanded by the converters, in the absence of a large receiving vessel, reservoir, or mixer, whatever you may be pleased to term it?

A. To have done this would have necessitated the tapping at one time of between 400 and 500 tons of metal, and it would have required the last ladles to have been held before use in the converting mill about five hours. Such would have been considered altogether a bad practice.

X Q. 336. And the same difficulties would be encountered in a lesser degree in running the entire cast of a single furnace into a series of ladles, instead of into one receiving vessel, would they not?

A. We have practiced this for the last fifteen years, both with and without our mixer, and we have not found that the objections would hold in this case, as mentioned in my previous answer, and by such objections I mean the chilling of the metal.

X Q. 337. Can you give me the relative loss from skulling between the blast furnaces and the converters in the case of using the ladles as in the direct process, and the practice with the mixer and its attendant ladles?

A. I had occasion after the introduction of the mixer to make a comparison as to the amounts of scrap made by the direct process and by the mixer process, the scrap representing the amount of skulling. To the best of my recollection, it was one-half of a per cent. loss with the direct process, and about one per cent. with the mixer process. This was at the Edgar Thomson works, in which the mixers are located at the blast furnaces. This scrap from skulling is not caused entirely by the radiation of heat from the molten metal, but is owing in part to the skulling of the
878 metal which is held back in the ladle by the clogging of the coke and refuse covering, which interferes often, when the pouring spout is either in good or bad condition, with a complete draining of the ladle.

X Q. 338. Can the Jones process, as you have interpreted and explained it in your testimony, be practiced in a charging ladle?

A. By "charging ladle" I understand the ladle that is used for pouring the heat into the converter, and I can conceive of no way in which it can be practiced, and as a matter of fact we use the charging ladle in the same way with the mixer as we did in the cupola process; and in the charging ladle is performed the same functions with the mixer as with the cupola, in which there is nothing new, while the Jones metal mixer is a new and distinct apparatus introduced into the manufacture of steel, which has added economies in addition to that performed by the charging ladle, and necessary after the introduction of the charging ladle for the development of the steel process.

X Q. 339. What do you understand to be the novel features or characteristics of the Jones mixing apparatus?

A. I meant by the term "Jones metal mixer" to include the apparatus and the method of operating it and the purpose for which it is used.

X Q. 340. I will again ask you in respect to what features or characteristics you speak of the Jones metal mixer as "a new and distinct apparatus"?

A. The new and distinct features of the Jones apparatus are that it is an appliance of such size and capacity and construction, and is operated in such manner by which the metal charged into it is prevented from losing its heat to a great extent and in which the inequalities of the charges are equalized and the temperature is supplied by frequent additions, and the withdrawals are practically uniform in composition, or changing only by slow gradations, in which the withdrawals are replenished by new charges and
879 which is provided to maintain a large pool of metal, the metal charged into which is obtained from a smelting furnace, and the metal withdrawn is used in a refining works, and so conducted as to make a continuous operation from day to day. This, as I understand it, with respect to the apparatus and the manner of

operating the apparatus, combined to make it a new and distinct apparatus.

X Q. 341. You have not answered my question. I now ask you, omitting all matters as to process and method of operation and dealing only with the Jones mixer as a mechanism, in what particulars or features do you consider that mixer new?

(Objected to as incompetent and irrelevant, the question seeking to eliminate the use of the apparatus which would render useless any piece of mechanism, and this suit relates to a method of use, apparatus being involved therein.

Defendant's counsel directs the attention of the court to this witness' voluntary statement respecting the Jones "new and distinct apparatus" in answer 338.)

A. I consider that I had answered your question in accordance with the matter indicated in your question 338, in which you asked if the Jones process can be practiced in a charging ladle, coupling together not only the apparatus, but also the method of operating it; and I am quite at a loss to describe a piece of apparatus without explaining the manner in which it is operated. I can only say that it is an enclosed or covered tank, made to tilt or revolve and adapted in construction, general arrangement and location to carrying out a well-defined process.

X Q. 342. Am I to understand that your last answer is the best description you can give of the Jones mixer as an apparatus and of its novelty?

A. I have explained it as fully as it occurs to me at this present moment.

X Q. 343. Are you not aware that the Patent Office denied
880 the novelty of Jones' broad claims on his apparatus, and that the patent as issued was restricted in its claims to features which are not used in defendant's Cambria apparatus?

(Objected to as incompetent and irrelevant and not proper cross-examination.)

A. I know nothing whatever in regard to what was decided at the Patent Office with respect to the Jones application for a patent on his mechanism. However, as I have previously stated, and I wish further to emphasize the fact in order to make it clear, that I understand by the use of the term "Jones metal mixer" to mean the appliance and the method of operating that appliance in detail as showing particularly for what new and distinct feature for which it was designed and constructed, and this I give from my practical knowledge of the art before the mixer was introduced and from the results obtained by its use.

(All after the word "mechanism" is objected to as irresponsive, voluntary and argumentative, and the attention of the court is respectfully directed to the treatment of the last three questions by the witness.)

X Q. 344. Referring to the Deighton patent, please give the num-

ber of the page and the lines in which it is stated that he drains his receiver or mixing vessel before recharging the same.

A. That is not stated specifically in the Deighton patent, but as I have been advised that patents are addressed to those skilled in the art, the method of operating such an apparatus would be in accordance with the method best suited to perform the operation, and to avoid, as completely as possible, all the practical difficulties that would naturally occur. The language of the Deighton patent is very obscure, and does not specify how he intended to operate it, and the method of its operation, as I have described it, is the way I would perform the operation myself, as the result of an extended knowledge in the handling of molten metal.

881 X Q. 345. What is there in the construction of the apparatus shown and described in the Deighton patent to prevent the tapping of the blast furnace in succession into his mixing vessel *m* and the drawing of converter charges from this vessel, as desired? Please bear in mind that I am dealing simply with the construction of the Deighton apparatus to allow or prevent the operation stated?

A. The Deighton apparatus being constructed without a cover, and, as I have explained fully in answer to Q. 178, if the apparatus was operated by successive casts of metal, being charged from one or more furnaces instead of simultaneously, it would, in my judgment, have become inoperative after working it a short time, for the reasons I have already explained, where the metal charges falling on top of the coke refuse would splash and chill. By filling at one time, this refuse could be brought to the top of the vessel and scraped off; whereas if the metal was put in in successive casts from the furnace, the height of the metal would vary up and down, but still be far below the top, and it would be practically impossible to remove the refuse from the top of the metal, it being so far below the efficient reach of the workman.

A person who has not had experience with molten metal freshly tapped from a blast furnace, can form no idea of the large amount of refuse material known as kish or graphite, which is separated from the liquid metal, accumulating in large quantities containing shotted iron intermingled with it which becomes set and encrusted; and this material being of such a nature that it is very light and slippery, it is even under the best conditions, with an overturned ladle, very trying to remove, and would naturally present a most difficult problem and be practically impossible to remove from a vessel at a point below the top. We have found in our practice that iron splashing on this material chills rapidly forming a crust,

882 and for this reason, there is a rule at our works, that it must be removed after every emptying of the ladle; and for this reason the Deighton apparatus is unsuited to be operated in any other way except by practically draining it and then refilling to the top. I would state further that we see the importance of removing this kishy material from our mixer. When the mixer is tilted and the metal is running out, a workman stands with a long hoe in his hand and reaches back into the mixer, pulling this ma-

terial forward so as to be carried out by the stream of metal, and this is done at nearly every withdrawal from our mixer, or frequently enough to prevent an undue accumulation. This was one of the difficulties that we encountered when we first began to use the mixer. We did not anticipate trouble of this sort, but immediately after starting the mixer, we built a wooden platform in front of it, at sufficient height for a workman to operate this hoe, and it was so necessary that we replaced this temporary structure with one of iron and brick, and have ever since kept a workman employed for this purpose.

X Q. 346. Does the Deighton patent in any way speak of or mention the use of the coke refuse to which you refer as objectionable?

A. The Deighton patent does not mention coke refuse. The reason I mentioned it is because it is the material used in covering the molten-metal ladles at the different works in this country. He would not need to use coke refuse. The amount of kish that would be liberated would make an ample non-conducting cover, as we see in our own practice that many ladles do not require a coke covering, the kishy material being ample. Another point which I might mention is that the iron coming down a runner in a blast furnace carries into the ladle a large amount of sand which likewise chills very rapidly, this sand being washed from the sides of the runner.

X Q. 347. Where in the Deighton patent do you find any statement that the top of the accumulated molten metal "would be far below the top" of his mixing vessel?

883 A. It is not necessary for Mr. Deighton to designate that, and as I understand the terms to apply to his decription of his vessel when filled by casts tapped successively, it is simply a matter of common sense. If metal is run into a receiver and charges are withdrawn before the next cast is put in the metal is bound to be a considerable distance below the top.

X Q. 348. Please read into the record from the Deighton patent every word on which you rely as indicating that Deighton did not propose to fill his mixing vessel *m* to the top or nearly so.

(Objected to as indefinite, the drawing being a part of the patent, and the evidence of this witness is based upon the patent as a whole, in connection with his knowledge of the art gained by actual experience.)

(The question is withdrawn.)

X Q. 349. Have you measured and calculated the relative capacity of the blast furnaces, the mixing reservoir *m* and the converters, as shown in the drawings of the Deighton patent and described in the specification thereof?

A. I have made no calculation on the matter in whole as referred to.

X Q. 350. What calculation, if any, have you made as to the relative capacity of the blast furnaces, the mixing vessel *m* or the converters, shown in the Deighton patent?

A. I have made no calculations on any of them but as indi-

cated in answer to Q. 241, I assume that fifty tons a day would have been a fair product for an English furnace at that time. I likewise indicated that the capacity of converters that were used about that time were in the neighborhood of about five tons, although I have no positive knowledge as to either.

X Q. 351. Please read into the record every word of the Deighton patent on which you rely as supporting your statement
884 that the top of the molten metal will be far below the top of the mixing vessel *m*? I ask you simply for the language of the patent, and not for your conclusions thereupon, as this would be a matter for the court.

(Objected to as indefinite and incompetent; also as not proper cross-examination, the witness having been called to give his testimony in regard to the Deighton patent, not only from the specification, but from the drawings, as they would be considered as a whole by one skilled in the art. His opinions and conclusions are therefore the only relevant matter in this connection, together with such matters of fact as are within his knowledge.)

A. The language of the patent is as dumb in furnishing a description of its method of operation, as the appliance was dead in practice.

X Q. 352. Am I to understand from your last answer that the patent does not contain any language stating that the top of the molten metal remains far below the top of the mixing vessel *m*, as asserted in your answer 345?

A. It is absolutely impossible to find anything in the patent giving in detail the method on which it should be operated, and it would seem to me as if that would be left to the judgment of any person who attempted to use it, it apparently not being clear to Mr. Deighton himself how it should be operated; and I would conclude that he had no definite plan in his mind for operating it, or he would have so expressed himself. The language of the patent as I read it explains nothing with respect to the question asked.

X Q. 353. Please quote from the Deighton patent the language, if any, which forbids the tapping of the furnaces successively into this mixing vessel *m*, or any language which forbids the keeping of the molten metal up to a level near the top of the vessel *m*. I would like to have the exact words of the patent and nothing else.

A. As stated before there is nothing pro or con on any detail of practice found in the Deighton patent. I am quite sure
885 if he had tried practically the tapping of furnaces successively into his mixer before he wrote his patent, he would have forbidden this procedure; and as far as forbidding the keeping of the molten metal up to a level near the top of the vessel, it would have been useless to have either approved or forbidden it, as it is beyond human agency to pour metal into a vessel, draw it out at the bottom, and still maintain it at a level.

X Q. 354. You have referred, in answer to 216, to a conversation with Mr. Fronheiser and Mr. Morgan. Mr. Fronheiser is now dead, is he not?

A. Mr. Fronheiser is dead.

X Q. 355. Is it not a fact that the direct process without a mixer is still being practiced by the Bethlehem Iron Co. of Pennsylvania?

A. I recently met Mr. John Fritz, until recently general manager of the Bethlehem Iron Co., and at the present time one of its stockholders, I believe, and likewise Mr. Owen Leibert, the present general manager of the Bethlehem Iron Co., and both of them informed me that they had recently began to use the metal direct from the blast furnaces without a mixer. Mr. Fritz informed me that he thought of going over to New York shortly, in order to see Mr. Carnegie, to see what arrangement he could make with him for using the metal mixer.

(Objected to as incompetent, it not appearing that this witness has personal knowledge of the fact.)

X Q. 356. Assuming the apparatus and the steps described in the Jones patent to be used, except that the mixing vessel is completely or practically emptied before being recharged; do you understand that that would fall within the Jones claim in suit to which you have referred?

(Objected to as not proper cross-examination, and also as calling for expert testimony in regard to the patent, as to which Mr. Gayley has not been called as a witness.)

886 A. In answering the question I can only state as to what the method of the Jones process is from the manner in which I have practiced it at the works; the conditions of the question are not those in which we practiced it, nor is it in accordance with the description of the process as formally set forth in the specifications, which clearly describe the manner of practice as it is carried out.

Adjourned to meet June 4th, 1897, at 10.30 a. m.

PITTSBURG, *June* 4, 1897.

Met pursuant to adjournment.
Present, as before.

Redirect examination by Mr. BAKEWELL:

R. D. Q. 357. You have been asked as to the absolute size of the charges to the mixer and their relation to the size of the mixer as stated in the Jones patent. Will you now say whether the patent states the amount of the charges to be added to the mixer relatively to the charges withdrawn therefrom?

A. As stated before, the specifications of the patent do not state in absolute terms what the quantity of additions should be. However, the language is sufficiently plain so that any person skilled in the art can approximate very closely as to the size of the additions in order to perform the operation and obtain the results as intended by the inventor. For instance, in the specifications, page 2, lines 118–120, it is stated that the metal is drawn off into cars 15, which cars supply the refining works and represent the quantity neces-

sary for the refining charge. On the same page, lines 45–46, it mentions how the mixer is to receive these charges. In lines 80–81, it mentions that the mixer is charged repeatedly by these cars. In the second claim of the patent, it is stated that there is introduced into a mixing receptacle successive portions of molten metal and the removing of portions only of the molten contents,
887 without entirely draining the same, and successively replenishing the receptacle. As replenishing means to fill up a vessel after the contents have been emptied or diminished, and as it is plainly stated that the purpose is to maintain large bodies of metal, it is clearly evident that in order to replenish the diminutions, the charges should be approximately equal in quantity to the withdrawals and varying therefrom only so far as would not disturb the uniformity or gradual changes of the successive portions withdrawn.

R. D. Q. 358. What indication is there in the patent as to the amount of the withdrawals from the mixer?

A. The amount or size of the withdrawals is the charge that is used for conversion, and in the ordinary practice of Bessemer steel works it is ordinarily a fixed and definite quantity, varying within small limits.

R. D. Q. 359. Taking the Jones patent in suit alone, without any other aid than his own common sense as a steel-maker, what obscurity would the patent specification present to the steel-maker desiring to operate the method therein described?

A. I can conceive of none; the size of the withdrawals are fixed practically and are to be replenished by frequent additions. The character and supply of molten metal from the blast furnaces is known and it would be very easy to calculate the capacity and size of the vessel to produce changes that were practically uniform in their character and composition. I cannot see any difficulty that would present itself to any practical steel-maker.

R. D. Q. 360. It has been suggested by some of defendant's witnesses that in the supplying of cupola metal to the converters the use of ladles adapted to contain more than a single converter charge was analogous in principle to the Jones method of mixing. Is there any analogy?

(Objected to as not competent in redirect, and as opening a new line of examination of this witness.
888 Counsel for complainant calls to the attention of the court that the cross-examination, both directly and indirectly, refers to this point.)

A. There is none whatever, as even with the use of the mixer the same use of the ladle is resorted to. For instance, we have at our Edgar Thomson works a ladle with a capacity when newly lined of 40,000 pounds, the average metal charge to the converter being 32,000 pounds, which ladle is always drained at the converting department. At the Duquesne steel works, the charging ladle has a capacity of 30,000 pounds, while the converter charge is 21,000 pounds, leaving a surplus capacity of 9,000 pounds, and the ladle

at this works is not entirely drained, several thousand pounds of metal being left over after pouring. We do not attribute any mixing functions on account of the metal left over in the ladle at the Duquesne works. The reason for having the greater capacity is simply the result of common knowledge around steel works that all open-top ladles will skull, and provision must be made for this skulling and interruption of its use, by replacing it with a clean ladle. This trouble, however, is not met with to any very great extent in foundry ladles, as they are used but a few hours every day, which gives an opportunity for cleaning between use. Deighton has also recognized that his apparatus would skull after the same manner as ladles, and his process be interrupted, as he has made provision for changing it, substituting a new one, just the same as is done with open-top ladles.

R. D. Q. 361. Will you state whether the use of the Jones method of mixing enables a steel works to obtain a product equal to that obtained when the converters are supplied with cupola metal, and whether the use of molten metal direct without the Jones mixer gives such result?

(Objected to as leading.)

A. I would state that we obtain in our practice equally as satisfactory results in every way with the use of the Jones mixer
889 as with cupola metal. We just recently introduced a metal mixer of the Duquesne steel works, where we were using cupola metal exclusively. Since its introduction we have used at times the mixer metal exclusively, and at other times part mixer metal and part cupola metal, and we find that the uniformity of practice in the converting mill is obtained equally well with the mixer metal as with cupola metal and is as uniform in character; and the character of our product, which is subjected to rigid inspection, is quite as uniform with the mixer as with the cupola metal, and with the advantage that the sulphur in the mixer metal is less. Our practice at Edgar Thomson, which came within my knowledge in the use of molten metal direct, showed that it was inferior to the Jones mixer metal.

R. D. Q. 362. Can you state, so that it may appear to the court, what is the saving effected by the mixer in getting a quality of steel equal to that obtained from cupola metal?

(Objected to unless the question is made to include the entire output of steel under each method.)

A. Mr. Moreland has stated, and has given the items for the cost of producing cupola metal at 65 cents per ton. The cost of operating the mixer and furnishing mixer metal is as follows:

For operating labor	$0.0083 per ton.
Repair labor	0.0058 "
Fuel	0.0010 "
Making a total of	$0.0151 per ton;

that is, making a total of one and one-half (1½) cents per ton.

R. D. Q. 363. You have stated in your cross-examination that you visited the Pennsylvania Railroad foundry at Altoona. Did you see anything there analogous to the Jones method of mixing?

A. I did not. They were using two cupolas, I believe, the
890 day I was there, each of which was charged identically the same, and the metal therefrom ran I believe through a common spout into the ladle. The metal was altogether uniform before it was charged into the ladle, and did not require any mixing or equalization of its constituent parts.

R. D. Q. 364. What was the position of Mr. Fronheiser at the time of your conversation with him about 1885?

A. He had charge of the department of the manufacture of pig iron, and I believe was designated as superintendent of blast furnaces. I think he was also called metallurgical engineer, but of that I am not certain. The works he was connected with was the Cambria Iron Company's works at Johnstown.

Complainant's counsel offers in evidence the blank form referred to by the witness in X Q. 299, marked "Complainant's Exhibit Gayley Blank Form," the same reading as follows:

E. 315 V. M. 1196.

The Carnegie Steel Company, Limited.

Daily Report of Operations of Edgar Thomson Furnace.

Charged.	No. of charges.	Weight per charge.	Total weight.	Product.	Weight in pounds.	Labor, in tons.
Ore,				Molten metal,		
Total ore,				Pig iron,		
Scale,	No. of charges,			Day,	Night,	Total,
Cinder,	Time lost,					
Scrap,	Cause,					
	Remarks:					
Total mixture,						
Coke,						
Limestone,						
Blast-furnace cinder,						
Charged into stack,						

(Objected to as incompetent if intended to establish any practice or understanding outside of complainant's works.)

891 Recross-examination by defendant's counsel:

R. X Q. 365. Will you state all the reasons for not emptying or draining the mixer in your Edgar Thomson operations?

A. I will endeavor to. One of the reasons is that by filling up the mixer and draining the same before refilling, we would simply be producing successive batches of metal, each differing from the preceding and succeeding batches, which would make irregularity in the operation of the converting mill and would approach in practical

results the former practice we used of intimately mixing the parts of a single furnace cast in a series of ladles, and which practice was abandoned by us as undesirable and uncertain. There would be no information given to the converting-mill man to enable him in rapid practice to connect one heat to another in point of working, such as is obtained with the mixer or cupola practice as used. It would have interfered with the operation of the steel works, as after draining, the converting mill would have to wait until the mixer was filled up, and again each batch in itself would have presented the greatest irregularity in the converting mill because there were no accessions of heat, as we find in practice at the Edgar Thomson works,—and this would illustrate what it means to empty the mixer before refilling, that with the first heat withdrawn and containing sufficient sensible heat to carry 1,500 pounds of scrap to the charge, through loss of heat with the diminishing volume, the amount of scrap is gradually reduced until the last two heats are blown on their side and only obtain sufficient heat before conversion by the combustion of the iron which is wasteful. We would, besides, in order to facilitate operations, have to run the quantity of molten metal necessary to fill the mixer into ladles and have it ready to dump in when the mixer was emptied. This would occasion in itself a further loss of heat, in addition to that radiated from
892 the mixer, and would require the introduction of more silicon into the metal, which increases the cost.

R. X Q. 366. Am I right in understanding that when you fill the Jones mixer in the first instance with successive batches of metal, you always obtain a homogeneous mass suitable for conversion?

A. We always did if the metal was not immediately drawn out before it had sufficient time for proper commingling.

R. X Q. 367. In operating your Jones apparatus, do you find it necessary to have the mixer filled up before you obtain a proper metal for conversion?

A. The rule of the works is to fill up the mixer at the beginning of the week before supplying the converting mill.

R. X Q. 368. Question repeated.

A. We have so considered it, and that is the basis on which we work.

R. X Q. 369. Am I to understand you as saying that, in working the Jones process and apparatus, the metal in the mixer does not become suitable for conversion until the mixer is filled up?

A. In order to fill the requirements of our works we aim always to keep our mixer full. We never begin to use the metal until the mixer has been filled, and after it is once put in operation we have a stipulated quantity below which we will not allow the mixer to be drained, as we find the irregularities in the converting mill are too great. We do not obtain a metal that changes by gradual gradation in such cases. Hence, while it is impossible to keep the mixer filled all the time, as the necessity for replenishing shows, yet we aim to prevent the mixer from being drained below the point at which we can obtain metal that is uniform or changing by gradual steps.

R. *D.* Q. 370. You have not answered my question. Do
893 you know that the metal in the mixer does not become suitable for conversion until the mixer is filled up? Kindly give this information and nothing else.

A. I would ask what period of time in its operation, in order to have fuller information, you refer to as the mixer being filled up?

R. X Q. 371. When you first put successive batches of metal into it.

A. Assuming that suitable metal is the best metal that can be obtained from the mixer, we obtain such suitable metal by filling the mixer. We have never in practice begun to draw from the mixer before it has been filled up, and as to whether it is suitable or not, it is an experiment that we have never tried, and while it could be converted in a steel mill, yet it is not as desirable.

R. X Q. 372. Have you ever analyzed or seen the analysis of metal from a mixer when it was but partly filled and before filling was completed?

A. I have already stated that we did not withdraw charges from the mixer when filling it up at the beginning of the week until the mixer was filled.

R. X Q. 373. How long have you known metal to be retained in a mixing vessel without additions thereto or subtractions therefrom?

A. I can't recall exactly, but it seems to me that we have had break-downs at the mill which may have lasted six or eight hours, possibly somewhat longer. I have been informed that it has been held at Chicago for 24 hours with the mixer partly filled and which they retained liquid by means of a gas flame, but I have not seen it done.

R. X Q. 374. The Edgar Thomson mixer which gives you cool metal for final heats is without any suitable heating apparatus, is it not, such, for example, as you have introduced at Duquesne?

A. That is correct.

894 R. X Q. 375. Where you use two mixers as at Edgar Thomson you introduce a ladleful of metal at a time into each mixer, do you not?

A. That is correct.

R. X Q. 376. As you read the Jones patent in suit, how many methods of mixing metal does it describe?

(Objected to as improper recross-examination.)

A. I really have not examined the Jones patent to determine how many processes are described. I have found therein in my hasty perusals of it a very clear description of the manner in which it is now practiced.

R. X Q. 377. In the course of your examination, you have answered many questions respecting matters described in the Jones patent, and in your redirect examination, in answer 357, you have quoted at length from the patent. I will now ask you whether in your examination of the patent you discovered more than one method or process of mixing described therein?

(Objection continued, and it is further stated that all questions relating to the construction or scope of the claims of the Jones patent are outside of the line of the direct examination of this witness, and that any questions that have come in as to this matter have been drawn in by counsel for respondent or through questions asked by him, and on this line of examination the witness must be considered as a witness on part of respondent.)

A. I only know of one, the details of which I have described as practiced by us, and in reading over the patent I would naturally observe the manner in which the description of the patent coincided with the way in which we practiced it. I have never examined it with the view of discovering any subtleties in the process or method.

R. X Q. 378. In your answer 360, you refer to the practice at Duquesne when the cupolas were used, do you not?

A. That ladle is in use at the present time, and is used for both cupolas and metal mixer. We have one ladle for both, and
895 my answer applies to both. We have not sufficient supply of metal at Duquesne for our mixer, and so far we have been using the cupolas for furnishing one-half or one-third of the supply for the converters; therefore, the ladle is filled every other time or every third time from the cupolas, as the case may be, the use of the ladle being the same in both cases.

R. X Q. 379. At Duquesne, how often do you reline or repair the lining of the ladles used between the mixer and the furnaces?

A. Whenever they are sculled about one-third full, which depends on the quality of the metal. Without having definite knowledge at the present moment, I would say about two days, under ordinary practice.

R. X Q. 380. You have been asked in your redirect examination respecting the cost of mixer metal. Will you give the total cost of the mixer metal from the time it leaves the blast furnace until it reaches the converter?

A. I have not this information with me.

R. X Q. 381. Can you give it approximately?

A. I would not attempt to approximate in matters of cost.

R. X Q. 382. Can you give the total cost of mixer metal between the blast furnace and the converter, as compared with the total cost of direct metal between the blast furnace and converter, when the mixer is not employed?

A. I have not these figures; they could only be furnished by the auditor of the company, who has access to the data necessary to procure them.

R. X Q. 383. Is not your knowledge of the Edgar Thomson operations such as to enable you to give approximately and with reasonable certainty the costs asked for in the last three questions?

A. As the question is one of labor, supplies, etc., and as we abandoned the direct process about nine years ago, I cannot
896 remember the number of men employed nor the wages that were then paid, nor the summarized data of these costs, to give any approximation that would be of any value whatever. As

a matter of fact, the question called for is, under our system of accounts, summarized under several different heads, and is not like other accounts represented exclusively under one item, therefore more difficult to recall. I referred the matter to our auditor at *noon, and he advised me that it would be considerable work to look* over the records in order to obtain it.

R. X Q. 384. When the mixer is used, the metal is handled twice, in ladles, instead of once, as in the direct process, is it not?

A. That is correct.

R. X Q. 385. And in this mixer process, there is a skulling in the first set of ladles and again in the mixer, and a third time in the second set of ladles, is there not?

A. There is skulling always in vessels handling iron.

R. X Q. 386. Can you give the percentage of seconds in the mixer process, as compared with the cupola process?

A. I do not know; I stated before that owing to a fire where certain of our records were kept, certain records were destroyed. Whether we have any left relating to the percentage of seconds under the cupola process, or not, I am unable to say, but if we have them we will be very willing to furnish them.

(Witness is requested to furnish such records, if possible, before the close of his deposition.)

R. X Q. 387. Can you give the percentage of seconds in the mixer process, as compared with the direct process, without the mixer?

A. I believe I have already stated that the records were destroyed, having been asked for some parts of them before, but that from a correspondence I found that I had stated to Sir Lowthian Bell, of England, that the second-quality rails have been reduced
897 from 6 to 4 per cent. with the mixer. That is the best information that I have at the present moment.

(Witness is requested to ascertain whether there are not records, duplicates of those destroyed, in charge of the auditing department, or other department of the complainant company, and if so, to furnish them before the close of his deposition.)

(Witness replies: When I instituted the last search I first made application to the chief clerk at the works, who consulted his predecessor, now not on active duty, as he had charge of the records at the period of time the matter referred to, and he advised me that no permanent records were kept, except the daily ones to make out the monthly report to be forwarded to the general office in Pittsburg. I then applied to the auditor of the company, and after an extended search he advised me that the records had been destroyed by fire.)

Redirect examination by complainant's counsel:

R. D. Q. 388. In answer to X Q. 379, you have stated that at Duquesne the mixer metal is used with cupola metal. Is this done in recognition of the fact, which you have previously stated, that mixer metal is the equivalent in quality to the cupola metal?

A. That is the reason we so use it, and we find it equal in every respect to cupola metal.

898 Recross-examination continued:

R. X Q. 389. Can you now produce from the records of the complainant company the statements showing the different blast furnaces from which the analyses referred to in your answer 9 were taken?

A. I herewith hand you the same. It is as follows:

Furnace.	Silicon.	Furnace.	Silicon.
C	2.01	G	1.31
I	2.05	H	1.03
E	2.19	D	2.17
F	1.17	C	1.59
G	1.10	I	2.08
E	2.31	D	1.66
H	.86	F	.84
C	1.19	E	1.87
G	.86	I	1.38
D	1.47	H	.91
E	2.10	F	.89
I	1.66	C	1.26
G	.75	D	1.54
H	1.28	E	1.77
F	.58	C	1.26
I	1.40		

R. X Q. 390. Can you also produce from the records of the complainant company the statement of the yearly tonnage of Bessemer steel produced at the Duquesne and Homestead works since 1887, as called for by Q. 308?

A. I herewith hand you the report of tonnage of the Homestead steel works covered by the period asked for, and the Duquesne steel works since it has been in our possession. It is as follows:

899 The Carnegie Steel Company, Limited, accounting department.

Statement Showing Tonnage of Bessemer Ingots Produced at Duquesne and Homestead Steel Works During Period as Shown Below.

Period.	Duquesne steel works.	Homestead steel works.
1888		111,710
1889		143,805
1890		140,939
1891	219,210	145,691
1892	265,436	97,135
1893	278,098	193,092
1894	339,247	257,646
1895	426,629	299,683
1896	401,851	211,724
1897 (5 months)	170,567	94,612
	2,101,038 tons.	1,696,037 tons.

Pittsburg, Pa., June 3d, 1897.

R. X Q. 391. I also called in Q. 306 for the record of the complainant company, showing the number and character of blows, percentage of seconds, etc., at the Edgar Thomson works for the months of July and August, 1893. Have you obtained these?

A. The percentage of seconds for July, 1893, was 11.64 per cent.; for August, 1893, 10.38 per cent. The records of operations in the converting mill I herewith hand you in the shape of our original record books.

R. X Q. 392. After examining the original record books of the converting department at the Edgar Thomson works, I can find no record showing the character of the blows. Did your company have any record at that time showing the character of the blows, that is as to whether the metal was hot or cold, and as to whether it was side-blown, and what way it was treated while in the converter?

900 A. The records presented are the only records which we kept at our converting mill. The question of temperature above normal is indicated by the amount of scrap carried. The question of temperature below normal is not recorded, as it did not call for the introduction of any additional metal or scrap to the blow. Moreover the practice of side-blowing did not affect the consumption of iron material, nor the quality of the steel. It was simply more expensive as a practice by the oxidation of the iron. This would be indicated on the record indirectly by calling for an increased percentage of ferro-manganese to remove the oxide of iron. At the same time an increase in the use of ferro or spiegel in the records would not show that conclusively, as a change might be made in the grade of ferro or spiegel used having a higher or lower percentage of manganese. A fair approximation might be made by observing the uniformity of the content of manganese in the steel, which would indicate to some extent the character and kind of blowing, but there is nothing in the records which will furnish an absolute guide as to the number of heats that were side-blown; we did not keep such a record.

R. X Q. 393. Please think on this and try and refresh your memory as to whether you did not receive daily reports for the months of July and August, 1893, and possibly for the months before and after those, showing the percentage of side-blown heats or the number of such heats per day?

A. I have already handed to you the original records covering all the data that was kept in our converting mill at the Edgar Thomson works. A report was handed to me daily on quite an elaborate sheet showing the practice of all the mills, and which record was made from the record books in the various departments, and that from the converting mill would be taken from the books that I have handed in, and if no record appears there of information asked for, there was none kept that I have any knowledge of.

R. X Q. 394. Are those daily reports to which you have referred preserved and are they still in existence?

901 A. That I cannot answer. I understood they were abandoned in 1895; they were carried on for about two years, or

three, possibly. I rarely ever looked at them, and we considered them of little value. I know during my time they were often used for wrappers and such as that.

R. X Q. 395. Can you now give me, as asked in Q. 386, the percentage of seconds in the mixer process as compared with the cupola process at Edgar Thomson?

A. The last complete year of cupola metal, 1882, the seconds were 3.25 per cent. The first complete year of mixer metal, 1889, the seconds were 4.25 per cent. The increase in percentage of seconds in mixer metal over cupola metal being due to an increase of rigidity of inspection.

R. X Q. 396. Can you now give the percentage of seconds in the mixer process at Edgar Thomson, as compared with the direct process without the mixer?

A. The first complete year of direct metal, 1885, the seconds were 6.09 per cent. The last complete year of direct metal, 1887, the seconds were 5.97 per cent. The first complete year of mixer metal, 1889, the seconds were 4.25 per cent.

R. X Q. 397. Can you now give the total cost of delivering molten metal from the blast furnaces to the converters at Edgar Thomson under the mixer process and the direct metal process respectively?

A. The cost of delivering molten metal from the furnace to the steel converter is, for mixer metal, 0.08^{76} per ton, and direct metal, 0.05^{75} per ton. In mixer metal cost, allowance is made for depreciation in value of scrap produced in excess of direct process. The Duquesne mixer being located at Bessemer department, would not have to consider an excess of scrap.

R. X Q. 398. Will you read into the record from the Edgar Thomson book which you have produced, the analyses showing the
902 silicon content in the metal delivered from the mixer to the converters from August 6th to August 11th, inclusive, 1893?

A. I will. They are as follows:

Date.	No. of blow.	Sil.	Date.	No. of blow.	Sil.
Aug. 6.	2460	1.12		2540	.98
	1	1.30		2	.79
	9	.07		4	1.02
	2471	.61		6	.93
	3	.56		2552	.98
	5	.51		4	1.00
	7	.75		5	.84
	9	.79		7	.98
	2481	.79		9	.93
	3	.91		2561	.96
	5	.91		3	.72
	7	1.03		5	.77
	9	1.12		7	.75
	2491	1.05		9	.70
	3	.89		2571	.55
	5	.65		3	.53
	6	.75		5	.63

Date.	No. of blow.	Sil.	Date.	No. of blow.	Sil.
	8	.82		2577	.65
	2500	.91		9	.70
	2	.91		2581	1.00
	4	.96		3	1.03
	6	.84		5	1.00
	8	.86		7	1.07
	2510	1.07	Aug. 8.	2594	1.02
	13	1.10		6	1.16
Aug. 7.	17	1.16		2600	.65
	19	1.26		2	1.12
Aug. 7.	2521	.89		4	1.07
	3	.70		6	.79
	6	1.07		8	1.12
	7	.89		2612	.89
	9	.93		14	.93
	2531	.79		16	.61
	3	.70		18	.61
	5	1.16		19	.70
	7	1.12		2622	.84
	9	1.07		4	.81
903	2626	.84		2717	1.26
	8	1.21		19	1.26
	2631	1.38		2721	.93
	2	1.40		3	.98
	5	1.31		5	1.17
	8	.91		7	1.10
	2642	.81		9	1.28
	4	.77		2731	1.19
	8	1.03		6	1.07
	2650	.77		8	1.19
	2	.65		2740	.79
	4	.79		2	.98
	6	.93		4	.89
	8	.84		6	.86
	2660	.98		8	1.00
	2	.98		2752	.96
	4	.98		4	1.03
	6	.77		6	1.03
	8	1.00		8	.89
	2670	1.03		2760	.68
	2	1.03		2	.70
	4	1.00		4	.77
	6	.93		6	.91
	8	.84		8	.86
	2680	.91		2770	.86
	2	.79		2	.93
	4	.91	Aug. 10.	6	.93
	6	1.21		8	.84
	8	1.10		2780	1.07
	2690	1.12		2	1.02
	2	1.14		4	.65

Date.	No. of blow.	Sil.
	4	1.14
	6	1.03
	8	1.14
Aug. 9.	2702	1.06
Aug. 9.	2705	.98
	7	1.07
	9	.93
	2711	1.16
	13	1.35
	15	1.16
904	2807	1.07
	9	1.16
	2811	1.26
	13	1.19
	15	1.10
	17	1.07
	19	1.00
	2821	1.05
Aug. 10.	2825	.89
	7	1.00
	9	1.03
	2831	1.03
	3	.86
	7	.98
	9	.98
	2841	.89
	2	.96
	4	1.00
	9	.91
	2851	.82
	3	.68
	5	.89
	7	.51
	9	.66
	2861	.51
	3	1.05
	5	.61
	7	.86
	7	.82
	9	1.07
	2871	.66
	3	.61
	5	.79
	7	.61
	9	.89
	2881	.79
Aug. 11.	6	.70
	8	.75
	2890	.84
	2	.89
	4	.65
	6	.79
	8	.93
	2790	.89
	2	.84
	6	.89
	8	.93
	2800	.89
	1	1.02
	3	.93
	5	1.07
	2896	.75
	8	.75
	9	.84
	2900	1.07
	3	1.12
	5	.93
	6	.84
	9	.93
	2911	.98
	13	.93
	15	.89
	17	1.12
	19	.98
	2921	1.02
	2	.84
	5	.67
	7	.70
	9	.96
	5	1.05
Aug. 11.	2942	.61
	4	.61
	6	.79
	8	.96
	2950	.98
	2	.70
	4	.72
	6	1.28
	2933	.98
	8	1.13
	2960	1.33
	2	.86
	4	.70
	6	.61
	8	.68
	2970	.75
	2	1.00
	6	.98
	8	.98

905 R. X Q. 399. At Edgar Thomson it was the practice to run occasional ladles of metal directly from the blast furnace to the converters in order to heat the latter up in the event of their growing cold under the use of mixer metal alone, was it not?

A. That was resorted to at times when the mill was operated below its normal capacity and when we were using four converters. The time between blows was so great and any lengthy stop on one vessel would necessitate an extra amount of heat to heat up. This could be done by burning coke in the converter, as is done at places where they do not have direct metal, but it is done more easily by us by simply sending up a ladle of iron directly from the furnaces. By certain improvements in our converting mill we are now operating by two converters to make the same product for which we formerly used four, and at the present time we would not have occasion to use direct metal in such way.

R. X Q. 400. Please have made and file with the examiner a report from the records of the complainant company showing the percentage by months of all the second-quality rails made at the Edgar Thomson works for the years 1895 and 1896?

A. I will endeavor to procure those records.

Redirect examination by complainant's counsel:

R. D. Q. 401. You have been asked in cross examination to give the comparative cost of delivering mixer metal and direct metal to the converters. Will you now likewise give the cost of delivering cupola pig metal when melted in cupolas to the converters, so that the same may be compared with the other figures?

A. The cost of delivering pig metal from the furnaces to the cupolas at the Edgar Thomson works is 13 cents per ton. According to Mr. Moreland's figures, as given in his testimony in
906 this case, for melting metal in cupolas is 65 cents per ton; hence the total from furnaces to converters would be 78 cents per ton.

R. D. Q. 402. You have been asked concerning the percentage of second-quality rails for July and August, 1893, at the Edgar Thomson works. Will you state whether there was anything which increased the percentage of these months above the normal, and if so, state the same.

A. The reason for the high percentage of seconds in 1896, is as follows:

In 1892 the practice was begun for the first time in the history of our Edgar Thomson works of rolling the rails directly from the ingots without reheating the blooms, aiming to obtain a better wearing rail by rolling at a lower temperature, and expecting that the increased percentage of second-quality rails would not offset the saving by not reheating the blooms. The project did not meet with favor from the railroads, and they inspected the rails more closely, thus rejecting more rails so of second quality.

In July, 24,532 tons of rails were made, and 23,680 tons in August, owing to dullness in trade; the usual output being 35,000

tons per month, running the mill slowly does not contribute to good practice in converting mill. At the end of August the mill shut down until October.

During 1893, when this experiment in direct rolling was being made, we began the building of additional heating furnaces for ingots, which at times interfered with the operating of some of the other heating furnaces.

R. D. Q. 403. There have been references throughout the testimony to the influence of the weather upon the character of metal produced from blast furnaces. Will you please explain briefly, showing the volume of air that is blown into a blast furnace, and to what extent the per cent. of moisture carried in thereby may vary from time to time?

A. In our furnaces of standard capacity we blow 35,000 cubic feet of air per minute. If the moisture in the air is one grain
907 per cubic foot, on this basis we blow in about 25 gallons of water per hour. The average content for the year is about 5 grains of moisture in a cubic foot of air, which would represent 125 gallons of water per hour going into the furnace in the condition of aqueous vapor. As is well known, the humidity of the air may change decidedly from day to day; as, for instance, in summertime, while today might have 5 grains of moisture in a cubic foot of air, tomorrow our hydrometer might show 8 grains, and sometimes 10 grains; thus changing suddenly from 125 gallons of water per hour to 200 or 250 gallons. This moisture must be dissociated in the hearth of the furnace and absorbs heat rapidly, causing violent fluctuations, and unless quickly perceived and controlled by manipulation of the hot blast. The change in the humidity of the air is the most troublesome element to contend with in the manufacture of pig iron, and the margin or surplus in the heating capacity of the stoves is not always sufficient to meet it.

R. D. Q. 404. Can you produce a blue print showing the drawing of the Edgar Thomson plant with the mixers and the route of the metal from the furnaces to the mixer- and from the mixers to the converters?

A. I herewith present a general ground plan of the Edgar Thomson works, showing what you ask for.

(Complainant's counsel offers the said drawing in evidence and the same is marked "Complainant's Exhibit General Plan of Edgar Thomson Works.")

JAMES GAYLEY.

908 *Testimony of P. T. Berg.*

P. T. Berg, a witness produced on behalf of the complainant in rebuttal, having been first duly sworn, testifies as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence and occupation?

A. P. T. Berg, age 43 years, residence Munhall, Allegheny county, Pennsylvania, occupation mechanical engineer for the Carnegie Steel Company, Limited.

Q. 2. What position, if any, did you hold at the Edgar Thomson steel works while Capt. Wm. R. Jones was superintendent of these works?

A. I was chief draftsman at the Edgar Thomson works at that time.

Q. 3. Do you remember the designing of the Jones mixing apparatus at the Edgar Thomson works?

A. I remember it very well.

Q. 4. What did you have to do with the designing of the mixer?

A. I prepared all the drawings under the direction of Capt. Jones and had general charge of the erection of the mixer plant.

Q. 5. In preparing those drawings what did you have to guide you other than the instructions that you got from Capt. Jones?

A. Nothing whatever except the instructions from Capt. Jones.

Q. 6. Will you state whether or not you knew of anything in the prior state of the art which aided you or Capt. Jones in designing the mixer or carrying out the method of its use?

(Objected to as leading, also as incompetent.)

A. I did not.

Q. 7. Will you state what were the general expressions of opinion at the Edgar Thomson works as to the operation of the mixer at the time when it was proposed to erect the same?

909 (Objected to as incompetent, the opinions of complainant and its employees having no bearing on the validity of the patent or the question of infringement.)

A. The general expressions of opinion at the Edgar Thomson were that the mixer would be a failure, that it would be impossible to keep the metal liquid and that the mixer would skull very badly.

Q. 8. Did this prove to be the case after the mixer was operated?

A. No, sir.

Q. 9. How long had you been engaged in Bessemer steel works prior to the erection of the Jones mixer?

A. Nine years.

Cross-examination by defendant's counsel:

X Q. 10. Did you personally take part in operating the mixer or controlling its operation?

A. No, I had nothing to do with the operation of the mixer.

X Q. 11. What was the percentage of loss by skulling during the first few months that the mixer was in operation?

A. I do not know.

X Q. 12. How long had you been at the Edgar Thomson works before the introduction of the mixer?

A. About nine years.

X Q. 13. Do you know how the loss from skulling when the mixer was used, compared with the loss under the direct process previously used at Edgar Thomson?

A. It was considerably less with the mixer, but how much I do not know.

X Q. 14. Do you know this from having made the tests or consulting the records?

A. No, simply from observation.

X Q. 15. What was, as far as your observation went, the percentage of loss from skulling under the direct process and the percentage under the mixer process?

910 A. I am not able to state any figures.

X Q. 16. Can you not even give the approximate figures?

A. Not even approximate figures, no.

X Q. 17. Why was the mixer given the elongated form and mounted on trunnions beneath it?

(Question is objected to as improper cross-examination.)

A. It is mounted on trunnions in order to be able to tip the mixer and pour the metal out. I don't remember any special reason for giving it the elongated form.

X Q. 18. Will you state in substance the nature of the instructions which Capt. Jones gave you for designing the mixer?

A. The Captain gave me instructions about the shape of the mixer, and the details of the tipping arrangements, and all details pertaining to the mixer plant.

X Q. 19. You have said that you knew of nothing in the prior art which aided you in designing the Jones mixer. To what extent were you familiar at that time with the prior English and American patents and publications, or with the printed reports of Alexander Holley, as rendered to the steel companies?

A. I was not familiar with the Holley reports, but, of course, had some knowledge of the English and American patents and literature.

X Q. 20. Were you at that time familiar with the English patent of Deighton, of 1873?

A. No.

X Q. 21. Were you familiar with the English patent of Durfee, of 1872, No. 685?

A. I was not.

P. T. BERG.

Adjourned to meet June 5, 1897, at 10.30 a. m.

911 PITTSBURG, *June* 5, 1897.

Met pursuant to adjournment.

Present, as before.

Testimony of James M. Camp.

JAMES M. CAMP, a witness produced on behalf of the complainant in rebuttal, having been first duly sworn, testifies as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence and occupation.

A. James M. Camp; age 38 years; residence Allegheny City, Pa.;

occupation metallurgical engineer and chemist of the Duquesne steel works of the Carnegie Steel Co., Ltd.

Q. 2. How long have you been engaged in the business of metallurgical chemist for steel works?

A. About 15 years.

Q. 3. Have you ever been at the works of the Pennsylvania Steel Co., at Steelton, Pa., and if so, when?

A. I was at the works of the Pennsylvania Steel Co., the 20th of last April, 1897.

Q. 4. Did you visit the Bessemer works of that company at that time, and if so, state whether you noted the means used for delivering the melted iron to the converters.

(Objected to as immaterial.)

A. I did, and on the day of my visit I found three cupolas were in service. The iron from these cupolas was run into a ladle of about 10 tons capacity. When the ladle was full it was transferred, by an electric crane on which it was suspended, to the nose of the converter, and its contents drained entirely into the vessel.

Q. 5. What was the capacity of the converters?

(Objections continued to this entire line of examination.)

A. They were about 10 tons capacity.

912 Q. 6. Then, as I understand you, the charging ladle, being of the same capacity as the converter, contained only a single converter charge. Is that correct?

A. It is.

Q. 7. Was this the only apparatus used at those works at that time for charging the converters?

A. It was the only apparatus in service at that time.

Q. 8. Did you see any other apparatus at that works for charging the converters?

(Objection continued.)

A. Other apparatus was there, but it was so covered with slag and rubbish that it could be hardly distinguishable.

Q. 9. What was that apparatus?

A. It consisted of a large ladle mounted on wheels, resting upon a hydraulic lift. From the looks of it, one could infer that it had not been used for quite a while. This was later confirmed by a statement made by one of the mill foremen that it had not been in service for about 18 months.

Q. 10. Have you ever been at the works of the Cambria Iron Co., and if so, when were you there last?

A. I was at the Cambria Iron Co. the early part of this year, 1897.

Q. 11. Will you state whether you saw there any experimental mixing apparatus, and if so, state generally what it was, and whether in the neighborhood of that apparatus you saw any evidence of failure or disaster in its use.

A. I saw there a tank, with a movable cover, properly lined on

the front of which were several openings, one above the other, with a trough leading to the converter ladles. The apparatus looked like it had been in service at one time, and lying on the converter floor was a large chill which resulted from the use of this apparatus; this I would judge to weigh about 40,000 pounds.

913 Q. 12. Can you from your metallurgical knowledge tell how and in what way this chill was formed? State what it was like and what you know about it.

A. This chill resulted from the non-ability of the man who tapped the mixer to stop the flow of iron at the proper time, and the result was that the ladle was run full of iron and overflowed on the converter mill floor.

(Answer objected to as incompetent, it not appearing that he was present at the time of, or that he had any personal knowledge whatever regarding the occurrence as to which he has testified, and the statements being apparently based on hearsay.

Complainant's counsel replies that the objection of counsel is improper, in view of the fact that the experiment in question was conducted in secrecy and without notice to us, and that by the testimony of the witness the complainant is doing its best to obtain knowledge of the facts which were thus withheld by the defendant.

Counsel for defendant objects to the allegations of secrecy, being advised that the operations with the mixer in question were carried on in the open converting works of the defendant then in operation as usual.

By COMPLAINANT'S COUNSEL: But within enclosed gates and without notice to us.)

Q. 13. Was this 40,000-pound chill still lying on the floor when you were there?

A. The chill was still lying on the converter floor, at one end.

Q. 14. Can you state in what esteem this experimental apparatus was held by the workmen at the Cambria Iron Co.'s works?

A. It was no good, was the opinion of two of the men, very dangerous to the man who taps the mixer on account of the high pressure of iron back of the tapping hole, and impracticable for that
914 reason, and also that the iron was so cold that they would have to sometimes shovel it out of the top of the mixer.

Cross-examination by defendant's counsel:

X Q. 15. At the time of your visit to the Pennsylvania steel works in April, 1897, those works in the converting department were being reconstructed or rearranged, or steps were in progress to that end, were they not?

A. I saw no signs of any changes being made at the time I was there, affecting the working of the converting plant.

X Q. 16. You understood, did you, that the electric crane and its ladle taking the metal from the cupolas to the converters, was a permanent arrangement?

A. So far as it was in service, it was permanent.

X Q. 17. Respecting the tank you saw at the Cambria works, did you see it in operation?

A. I did not.

X Q. 18. Did you see the chill to which you have referred, formed?

A. No.

X Q. 19. What was the capacity of the ladle which you saw adjacent to the tank at Cambria?

A. I would judge it to be between 15 and 20 tons capacity.

X Q. 20. How did you gain access to the Cambria works at the time you saw this tank?

A. I went to the office, gave my name to the watchman, who disappeared and returned shortly with a pass.

X Q. 21. You had no difficulty in obtaining a pass?

A. Apparently, not.

X Q. 22. It is custom, is it not, at Cambria to admit as visitors people of apparent respectability on application to the office?

A. I can hardly answer that question, as one trial does not make a precedent.

915 X Q. 23. Did you give your occupation and place of business when you applied for the pass?

A. My recollection does not cover the point if such were asked. If such were asked, my occupation at that time was given.

X Q. 24. What was the date of your visit to Cambria?

A. I can't make it any closer than I have stated, the early part of this year.

X Q. 25. You have no actual or personal knowledge, have you, as to the manner in which the chill at Cambria was formed or as to the length of time for which the tank was used, or the frequency with which it was tapped successfully, or how many times it was successfully tapped, or whether it was actually used for days continuously, in the manufacture of commercial steel?

A. I have not, excepting that which I have already given, which was obtained from the mixer foreman and the vessel foreman, separately and apart, and whose stories agreed in every particular.

X Q. 26. Then all you know about the Cambria tank is that you saw it when not in action, and that you saw a chill on the floor? I mean so far as any direct and positive knowledge on your own part is concerned?

A. It is true, but it is also true that a man with some little metallurgical skill could see and judge how the chill was formed without other testimony or statements by the employees.

X Q. 27. Have you any knowledge as to whether that tank was successfully used after the date of the formation of the chill?

A. I was informed that after the chill was formed the entire apparatus was abandoned.

X Q. 28. Who told you this?

A. The two foremen mentioned before.

X Q. 29. Can you give their names?

A. I cannot.

916 X Q. 30. Can you give me any description, facts or circumstances by which these foremen can be identified?

A. That was their occupations as they gave them to me at that time, and I have no other means of identifying them.

X Q. 31. Have you seen either of these foremen since?

A. No, sir.

X Q. 32. Of what departments were they foremen?

A. As before stated, they gave their titles as mixer foreman and vessel foreman.

X Q. 33. But you cannot give their names or describe them to enable me to identify them?

A. I wouldn't know them myself if I should see them.

X Q. 34. Did you visit the Cambria works more than once in 1897?

A. That was the only instance so far.

X Q. 35. And you are unable to say whether this visit was in January or February, or March or April?

A. It was not later than March.

X Q. 36. And you don't know personally whether the unknown workmen with whom you talked on an unknown date had anything whatever to do with the operation of the tank, or whether they saw it in operation, do you?

A. The men were certainly employees of the works, and were working during the time; our conversation took place between heats.

X Q. 37. But you do not know that these men were employed by the company during the previous year when the tank was operated, do you?

A. I had their statements to the fact that they were present.

X Q. 38. And that is all you know about it?

A. That is all I could know about it.

(The deposition of this witness so far as it refers to the operation of the Cambria plant is objected to as based wholly on hearsay.)

J. M. CAMP.

917 *Testimony of Wm. H. Conner.*

WILLIAM H. CONNER, a witness produced on behalf of the complainant in rebuttal, having been first duly sworn, testifies as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence and occupation.

A. William H. Conner, age 56 years, residence Pittsburg, Pa.; occupation superintendent of the Edgar Thomson foundry department.

Q. 2. In your department will you state whether castings are sometimes made of blast-furnace metal?

A. We make ingot molds of blast-furnace metal.

Q. 3. Will you state, if you know, whether metal from the mixer is suitable for making castings?

A. No, sir; it is not, in my judgment.

Q. 4. Why?

A. The metal is entirely too thick—too dead.

Q. 5. When in the foundry you get metal from the blast furnace that is too dead for making castings what is done with it?

A. When the iron is too dead for making ingot molds we send it back to the mixer.

Cross-examination by defendant's counsel:

X Q. 6. When you refer to "mixer metal" being unsuitable for casting ingot molds I suppose you refer to the mixer metal as you make it for use in the Bessemer process. Is this correct?

A. When the metal is put in there they use it for the Bessemer process and is not fit for us.

X Q. 7. Why is your Bessemer mixer metal unsuitable for ingot-mold castings?

A. It is entirely too dead.

X Q. 8. Explain what you mean by being too dead?

A. It loses its initial heat, it is too thick, and makes our molds all cold shot.

918 X Q. 9. The mixer metal as you have tried it for castings had been twice transferred, had it not, once in ladles to the mixer, and again in ladles from the mixer?

A. Yes, sir.

X Q. 10. Is the cupola metal hotter, or has it greater initial heat than mixer metal?

A. Of course, if you use it immediately after it is tapped out of the cupola, it is hotter.

X Q. 11. Does metal always come out of the cupola at the same temperature?

(Objected to as improper cross-examination.)

A. No, sir.

Testimony of Thomas James.

THOMAS JAMES, a witness produced on behalf of the complainant in rebuttal, having been first duly sworn, testifies as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence and occupation?

A. Thomas James, age 49 years, residence at Braddock, Pa., master mechanic for the Edgar Thomson steel works.

Q. 2. How long have you had that position?

A. I have been with them for 24 years.

Q. 3. Were you at the Edgar Thomson works when Capt. Jones designed his metal mixer?

A. I was.

Q. 4. Will you state whether Capt. Jones spoke to you about this metal mixer before it was built, and if so, what you said, if anything, about the way in which it would work or what would happen if you attempted to work it?

(Objected to as incompetent, the opinions of the complainant and

its employees having no bearing on the validity of the patent in suit.)

A. Capt. Jones told me he was going to build a mixer to
919 hold 100 tons of metal, and I told the Captain that he would have to build a crane that would lift 100 tons; that I thought it would only be a question of time until it would chill up solid.

Q. 5. As a matter of fact, did it chill up when it was put into use?

A. No, sir; I was mistaken.

THOMAS JAMES.

No cross-examination.

Testimony of John M. Sherrerd.

JOHN M. SHERRERD, a witness produced on behalf of the complainant in rebuttal, having been first duly sworn, testifies as follows in answer to questions by complainant's counsel:

Q. 1. State your name, age, residence, and occupation.

A. John M. Sherrerd, age 38 years, residence High Bridge, New Jersey; occupation, at present sales agent for the Taylor Iron & Steel Company; formerly superintendent for the same company.

Q. 2. Have you been employed at the Albany & Rensalear Iron & Steel Co.'s works at Troy, N. Y., and if so, when and at what capacity?

A. I went to Troy in the fall of 1881, succeeding the late Dr. August Wendell as chemist of the Albany & Rensalear Iron & Steel Co., and remained with that company and its successor, the Troy Steel & Iron Co., until December 1, 1894, in the capacity of chemist in charge of the metallurgical part of the works.

Q. 3. When you were at the Troy Steel & Iron Co. what was your relation to the converting department?

A. I had charge of the metallurgical part of the making of the steel as distinguished from the mechanical.

Q. 4. Will you state whether at those works cupola furnaces were used for melting the converter charges, whether the ladles in which the metal was tapped from the cupolas were of larger ca-
920 pacity than a single converter charge, and if so, what was the purpose of having ladles of such larger capacity?

A. Cupola furnaces were used, and ladles of somewhat larger capacity than a converter charge were used to receive the molten iron from the cupolas. The ladles were made somewhat larger than the converter charge, because if not made larger they would not be able to draw a full converter charge from the ladle after a skull had formed in this ladle, without removing the skull. Having a ladle of larger capacity than the converter charge, a skull to quite a large extent could be formed without throwing the ladle out of service.

Q. 5. Will you state whether in using such ladle of larger capacity than a converter charge, there was any purpose of obtaining an equalizing or mixing effect upon the metal, or whether any substantial mixing of the metal of the several charges with the metal of the preceding charge was effected thereby?

(The question is objected to so far as relating to the purpose of equalizing the metal, because it is not shown that this witness had knowledge of what the purpose of the designers of the plant was in this regard.)

(By COMPLAINANT'S COUNSEL: Let the witness state whether his official position in the works was such that if any purpose, such as named in the question, was sought to be effected by the use of this ladle in the works, the same would become known to him.)

A. If the purpose was to effect a mixing of the charge with the preceding one, my official connection with the company was such that I would have been acquainted with it. As a matter of fact, the ladle was drained as nearly as possible for each converter charge, as any metal remaining in the ladle would cool off, and, if anything, cool the succeeding charge that was tapped upon it. Our practice was to run the fuel consumption of the cupolas to as
921 low a point as possible, and any cooling effect of this kind was exceedingly undesired.

Q. 6. Will you state whether during your connection with the Troy works it ever occurred to you, or whether you heard it stated by anybody, that that ladle was desirable for the purpose of enabling components of the converter charges to be mixed with the components of the preceding charges, or whether you ever heard the ladle spoken of as desirable in any way for mixing purposes?

(Objected to as irrelevant and immaterial.)

A. No.

Q. 7. In the Troy works while you were there, did you use in Bessemer converters any metal taken directly from the blast furnaces, and if so, will you state what difficulty, if any, you experienced in such practice?

A. The converting works were rebuilt about 1886, and were then so arranged that metal from either cupolas or blast furnaces could be used. The blast furnaces were situated on an island, across the main channel of the Hudson from the steel works. The iron was brought from the furnaces to the steel works in ladles on cars. Great trouble was experienced, due to the irregularity of the metal as it came from the blast furnaces. At times, the metal would be entirely too hot to blow satisfactorily, and at others it would be so cold that not all of it could be poured from the ladle. The part remaining in the ladle formed a skull which might be partially cut out by the next succeeding charge from the blast furnace, or might be added to, and I have known the metal to be so cold that only 40 per cent. or even sometimes less has been drawn from the ladle. The composition of the metal also varied considerably, at times being entirely satisfactory, and at others being very unsatisfactory. These irregularities caused a very great deal of trouble in the converting department, as lots of metal had to be taken care of promptly on their receipt, and the blower not always knowing what
922 changes to expect, was liable to make mistakes in his calculation, the result being either metal too cold to pour, or too hot to make good steel.

Q. 8. Have you seen the operation of making Bessemer steel with the use of the Jones mixer at the Edgar Thomson steel works, and if so, will you state whether the difficulties you mention in your last answer were experienced when the Jones mixer was employed?

A. I saw the Jones mixer in use at the Edgar Thomson steel works not a very great while after it had been put in, I think in the fall of 1889, and on its operation being explained to me I was struck with the benefits to be derived from the getting metal free from the sudden changes in composition and temperature, and this point I appreciated very thoroughly when we commenced to use direct metal from the blast furnaces at Troy without a mixer, some two or three years later. The blower or scrapper has to determine how to handle a heat very quickly, and he bases his judgment somewhat upon the heat phenomena connected with the preceding charge of metal. He has means at hand to control quite wide variations in composition and temperature, and can take advantage of these means if only warned in time. It has been my experience that the metal coming from the blast furnace is liable to vary greatly in both composition and temperature from cast to cast, and these variations are so great that the blower or scrapper has little to guide him to the successful manipulation of the charge. The metal coming from the Jones mixer, on the other hand, changes comparatively slightly from ladle to ladle, and he can accommodate himself readily to these changes.

Q. 9. How long, and in what capacities have you been connected with Taylor Iron and Steel Company of High Bridge, N. J.?

A. I went to High Bridge January 1st, 1895, as assist- to the then general manager, Mr. William G. Neilson. I was afterwards appointed superintendent, and since April 1, 1897, have been acting as sales agent.

923 Q. 10. Are you familiar with the practice at the Taylor Iron and Steel Company's car-wheel foundry of tapping the metal from the cupolas into the ladles set in front of the cupolas, and pouring the metal from these ladles into small casting ladles or shanks?

A. Yes.

Q. 11. Will you state whether at those works each cupola has its own receiving ladle, or whether the metal from two or more cupolas is run into a common ladle?

A. We have in use at High Bridge four cupolas; the two largest ones have each a receiving ladle, but the cupolas being situated some distance apart, each ladle can receive the metal from its own cupola alone. The other two cupolas are small ones, and have no fixed receiving ladles, nor can they be tapped into the receiving ladles of the largest cupolas.

Q. 12. What is the capacity of the two ladles of which you have spoken?

A. I think they hold about five tons apiece.

Q. 13. Will you state whether there is now in use at the works any large ladle, of say 20 tons capacity or thereabouts?

A. No.

Q. 14. Has there been since you have been at High Bridge?

A. No, not since I have been there.

Q. 15. Then, as I understand you, if there ever was any such large ladle in use at this foundry, its use has been abandoned. Is that correct?

A. Yes.

Q. 16. Will you now state what purpose is accomplished by using those ladles in front of the cupolas at the foundry of the Taylor Iron & Steel Co.?

A. The ladles are foundry conveniences, used to render the casting process in a measure independent of the melting process;
924 in other words, the melter can work his cupola to best advantage by tapping the molten metal into the ladle when it is most convenient for him to do so, while the men who are pouring the metal into the molds can fill their hand ladles from the receiving ladle at their convenience, and hold the metal in the casting ladle until it acquires the proper temperature for casting.

Q. 17. You say you have seen the Jones method of mixing as practiced at the Edgar Thomson works. Will you state whether, as a matter of fact, this practice at High Bridge with which you are familiar, ever suggested to your mind any resemblance or substantial analogy to the Jones method?

A. I cannot see that the practice at High Bridge ever suggested any resemblance to the Jones mixer on account of the very great difference in the object sought and obtained.

In the cupola practice, it is always considered necessary to thoroughly mix the charges of iron before putting them in the cupola, so that the mixing is accomplished during the melting, and the product is practically homogeneous. On the other hand, in blast-furnace work, we have metal varying considerably in both composition and temperature from cast to cast. By putting the blast-furnace metal through the Jones mixer in the manner employed at the Edgar Thomson steel works, any abnormal charge added to the large amount of metal in the mixer changes the composition and temperature of the whole mass so very slightly that the successive charges drawn from the mixer vary only slightly from each other. This variation, though it may be over a very great range, is so gradual that the blower or scrapper can very readily accommodate himself to the changes from ladle to ladle.

Q. 17½. Will you state whether this practice of previously selecting the iron for the cupola charges was followed in charging the
925 cupolas of your Bessemer plant at Troy and the cupolas at the car-wheel foundry at High Bridge?

A. Yes.

Q. 18. What metallurgical experience and education have you had other than at the works of the Troy Iron and Steel Co. and its predecessor, and the Taylor Iron & Steel Co.?

A. I graduated at Lafayette college in 1878 as mining engineer and chemist. I took a post-graduate course at the School of Mines at Columbia college in the winter of 1878–1879, was appointed

chemist of the Secaucus Iron Co., Secaucus, N. J., and remained there until the fall of 1881, when I went to Troy.

(Defendant's counsel objects to all that portion of the evidence relating to the practice at the Taylor Iron & Steel Co. as irrelevant and immaterial, it being long after the date of the patent in suit.)

Cross-examination by defendant's counsel, without waiving objection:

X Q. 19. When you went to the Troy steel works, who were above you in the management of those works?

A. Capt. Robert W. Hunt was superintendent at that time.

X Q. 20. Was he the only officer or employé of the company who was above you in the management of the works?

A. Up to a certain time there was a superintendent of the steel works; I can't place the time of his leaving. It was some time about 1885 or 1886; his name was C. T. Ahrnberg. After that time until Capt. Hunt left he was my only immediate superior officer.

X Q. 21. Do you know who originally designed and erected those Troy works?

A. It was my impression that Mr. Holley designed the works originally.

926 X Q. 22. Was it understood that Mr. Holley had any connection with those works while you were there, in advisory or other capacity?

A. Mr. Holley died about 1882. I don't know what his relations to the company were at the time of his death. I do not know that they were very close.

X Q. 23. It is a fact, is it not, that Capt. R. W. Hunt directed the running of those works up until about 1888, when he left?

A. As general superintendent he certainly did.

X Q. 24. And he was the person of all others who would know why certain practices were followed in those works during that time?

A. I would say here that the works were redesigned by Capt. Hunt to a certain extent along in 1885 or 1886, and of course at that time the men directly under him were in consultation about various changes of the plant. What I meant to infer was that while these plans were being gotten up, of course the heads of the departments were familiar with the changes proposed, and of course Capt. Hunt would be in a position to know what had been proposed by different parties.

X Q. 25. I do not think you have answered the question I intended to put to you, at least. I wanted to know whether Capt. Hunt as general superintendent of the works was not the person of all others who would know why certain practices were followed in those works? Please answer this.

A. I should say yes, except as to details.

X Q. 26. Do you remember the normal charge to the converter employed when you first went to those works?

A. About eight tons.

X Q. 27. And what was the capacity of the charging ladle at that time?

A. I can't give the capacity of the ladle; I know it was somewhat larger than the converter charge. I can remember it now, it was about ten tons.

927 X Q. 28. How many cupolas did they use then for melting charges for the converters?

A. We had three cupolas then, and used two at a time, and occasionally all three would be in use.

X Q. 29. And about what was the weight of each tap or cast from each cupola into the charging ladle?

A. It was the practice to tap all cupolas in use at the same time, and shut them off when the proper amount of iron was received in the ladle.

X Q. 30. That is not answering my question. Please do so.

A. It was the aim to have the cupolas melt uniformly, so that in tapping about an equal amount could be obtained from each cupola, but as a matter of fact one cupola might be melting faster, one more slowly than the others, and more or less iron be obtained from any one cupola. The cupolas were all tapped at once and run through a common spout into a common ladle.

X Q. 31. Why did one cupola melt faster or slower than another?

A. After the cupola has been in use it commences to clog up more or less, and this clogging may not occur equally in all cupolas in use at any one time, or one cupola might cut out more than another, thus increasing its capacity considerably.

X Q. 32. What effect did this have upon the metal melting in the cupola?

A. A cupola clogged up would melt more slowly than one that was open. The iron itself would be practically of the same composition.

X Q. 33. Did the difference in the working of the cupolas have any effect upon the temperature of the metal coming from the different cupolas?

A. I should say that it had, because we sought to overcome any changes that are liable to occur by adjusting the cupola

928 charges—I mean the metal going into the cupola. What I mean is, that we varied both the mixture and the amount of fuel of the cupola charge, if necessary.

X Q. 34. How did you discover that this variation in the mixture and the amount of fuel in the cupola charge was necessary?

A. It was discovered by experience of the man in charge of the cupolas; he would know from his experience whether it was desirable to have any change in the mixture going into the cupola.

X Q. 35. What would indicate this to the man in charge of the cupolas?

A. The man in charge of the cupolas would know how each cupola was working, whether melting slowly, normally or rapidly, and his experience would indicate to him what changes would be desirable.

X Q. 36. Did the metal coming from the cupolas give any guide to him in ascertaining whether it was desirable to make a change?

A. He could tell, of course, from the appearance of the stream of metal whether it was working normally or not.

X Q. 37. What would the appearance of the stream from the different cupolas indicate?

A. It would indicate the temperature of the metal to a certain extent.

X Q. 37½. That is to say, that the metal coming from one cupola would be hotter or colder than that coming from another cupola?

A. That is correct.

X Q. 38. You say that you visited the Edgar Thomson works and saw the Jones mixer in the fall of 1889, and that you commenced to use direct metal from the blast furnace at Troy two or three years later. Your first use of blast-furnace metal at Troy was therefore about 1891 or 1892, is that correct?

A. As nearly as my memory serves me.

Adjourned to meet June 8, 1897, at 10.30 a. m.

929 PITTSBURG, *June* 8, 1897.

Met pursuant to adjournment.

Present, as before.

Cross-examination of Mr. SHERRERD resumed:

X Q. 39. How far were the blast furnaces which were located on the island of the Hudson from the converter plant of the steel works of the Troy Iron & Steel Co.?

A. In a direct line about one thousand feet, I should judge, but on account of the necessity of crossing the river by ferry instead of by boat, the tracks had to take a roundabout course, probably making the distance traveled in the neighborhood of three-quarters of a mile.

X Q. 40. Did this ferry belong to the company, or was it the public ferry over to the island?

A. It belonged to the company and was in no sense a public ferry.

X Q. 41. At about what intervals did the boat run?

A. The boat was operated solely for the benefit of the company, and it had no regular intervals between its trips.

X Q. 42. For what purpose was the boat employed?

A. It was used for transporting men and materials from the east bank of the river to the island.

X Q. 43. In hauling this blast-furnace metal, about what would be the shortest time between the tapping from the blast furnace and the delivery to the converter, and what would be the longest time for the same?

A. We counted on from about 20 to 30 minutes from the time the blast furnace was tapped until the ladle was received at the converting mill. Under particularly favorable conditions the time

was shortened somewhat. Under one very unfavorable condition the time was lengthened to over four hours.

X Q. 44. What delays were liable to occur in the bringing of the metal from the blast furnaces to the converter-house?

930 A. The ladles were on cars running on a narrow-gauge track; the track on the boat was connected with the track on the landing place by the ordinary means of a bridge and float; the upper Hudson is narrow at Troy and comparatively shallow, but subject to great variations in the depth of water. When the water was very low, the time employed in connecting the ferry-boat with the bridge was longer than at a medium stage. This same condition occurred when the water was exceptionally high, the bridges and floats being arranged for medium stages of water. At that point the channel of the Hudson was a public highway and trips were occasionally lengthened on account of the necessity of waiting until other vessels, particularly boats towing strings of canal-boats, were out of the way. At particularly low stages of the river the boat occasionally grounded. This last occurrence was an exceedingly rare one.

X Q. 45. How many cars of molten metal would you generally bring at a time from the blast furnaces to the converter mill?

A. One, two or three.

X Q. 46. How long was the usual period between blows or conversions at the converter mill, and did this vary?

A. At the time direct metal was used at Troy we were working the converting mill under unfavorable conditions, as we had to cast the steel in a comparatively large number of small ingots. On this account the conversion was carried on comparatively slowly, only some two heats per hour being employed. There was not very much variation.

X Q. 47. Then if you brought three car-loads of molten metal to the converter mill at one time, the last car-load would wait for about an hour before conversion, would it not?

A. The practice of sending three ladles of metal to a trip was very soon abandoned, but while it was in use the third ladle had to wait about the time mentioned.

931 X Q. 48. Is it not the fact that at the Troy works, on account of these difficulties, they have erected a converter mill on this island close to the blast furnaces?

A. When I was relieved at Troy, the Troy Steel & Iron Co. was in the hands of a receiver. It is my understanding in the matter that the company has been reorganized and is now known as the Troy Steel Co. After reorganization, the old Bessemer converting plant on the east bank of the Hudson was torn down and a new plant for the manufacture of steel by the basic Bessemer process was erected on the island not very far from the blast furnaces.

X Q. 49. Referring to the Taylor iron & steel works and to the receiving ladle employed at the two largest cupolas there, were these cupolas and ladles employed in the same way during all the time that you were there?

A. Yes.

X Q. 50. About how much metal per day was melted in each cupola?

A. One cupola has been used only one day to my knowledge since I have been there. The other cupola has been in pretty constant use, and melts in the neighborhood of 25 tons per day.

X Q. 51. During what part of the day was the operation of casting the car wheels conducted in that foundry?

A. All the casting was conducted in the afternoon.

X Q. 52. Please enumerate all the articles made from the metal melted in that cupola?

A. In that cupola material for car wheels almost exclusively was melted, but at times other castings were made from the same metal.

X Q. 53. Now please describe the way that this 25 tons of metal was conducted to the receiving ladle?

A. When the melter found the cupola to be in proper condition to be tapped, he commenced filling the succeeding ladle, and whenever the foundry foreman determined, the hand ladles were filled from the receiving ladles.

932 X Q. 54. About what weight of metal did the hand ladles hold?

A. A little over 1,200 pounds, enough to pour two wheels.

X Q. 55. About how often was the cupola tapped into the receiving ladle?

A. I can't say in minutes; I should say the operation was over in a little over an hour.

X Q. 56. Was the metal in the receiving ladle stirred at all after it was tapped from the cupola into the same?

A. I never saw it stirred but once that I remember.

X Q. 57. Do you remember why it was stirred then?

A. There was a small skull in the bottom of the ladle, and we wished to melt it out if possible.

X Q. 58. How thickly was this ladle lined?

A. It was built up with the usual loam lining. I think the usual practice was from 4 to 6 inches. I can't give the exact thickness.

X Q. 59. Were the wheels produced the ordinary chilled car wheels, or was there anything special about them?

A. Our principal product was chilled car wheels which had to conform to the specifications of the companies purchasing them. As these specifications varied slightly, some modification of the mixture of irons charged into the cupola was required at times.

X Q. 60. Generally speaking, you charge that cupola with pig metal, steel scrap and old car wheels; is that correct?

A. It is correct, if you include in the term "old car wheels," car-wheel scrap. By car-wheel scrap is meant defective car wheels and runner scrap produced around the foundry.

X Q. 61. Did the old car—wheels or car—wheel scrap charged into the cupola vary as to the weight and sizes of the pieces of such metal charged to the cupola?

933 A. It is of course quite impracticable to break up scrap to perfectly uniform size, but it is our endeavor to have these pieces of scrap as nearly of one size as practicable.

X Q. 62. In the running of the cupolas at the Taylor Iron & Steel Company, did you ever have any difficulty as to the working of the same, such as the cupola melting slower or faster, or clogging up, etc.?

A. I cannot say that it was every day exactly alike.

X Q. 63. In employing the cupolas at the Troy works, did you melt down the steel scrap produced in the works in these cupolas?

A. We endeavored to use up the steel scrap as produced, partly by melting in the cupolas, partly by throwing into the converter, and occasionally charging in the blast furnace.

X Q. 64. Did the scrap which you melted in the cupolas vary in weight of the pieces, or did you break that down to size?

A. The scrap of course varied in size, but we broke the larger pieces to as small a size as practicable.

X Q. 65. And this steel scrap was charged to the cupolas with the pig metal?

A. That part of the scrap which was used in the cupolas was of course charged with the pig metal.

X Q. 66. What was the capacity of the ladles on the cars that you employed for transporting the metal across the river to the converter mill at Troy?

A. The normal charge was about ten gross tons, but the capacity of the ladle was probably 25 per cent. greater.

X Q. 67. Was any means employed to prevent the cooling of this metal in the ladles during transportation?

A. There was a light covering of charcoal or coke braize dusted over the top of the metal.

X Q. 68. What was the ordinary cast of the blast furnaces on the island at Troy?

934 A. While direct metal was being used, the number of casts was varied to accommodate the ladles and averaged about an interval of two hours and forty minutes between tapping of the furnace. This casting or tapping was aimed to produce two ladles full of metal, averaging about 10 tons each. If there was an excess of metal after the two ladles were filled, it was run into pig beds.

X Q. 69. What was the ordinary time for castings and weight of casts from those furnaces when you did not use the molten blast-furnace metal in the converters?

A. We cast six times a day, and the cast averaged somewhat over 30 tons.

X Q. 70. In answer 7 you say that the converting mill at Troy was rebuilt about 1886, and was then so arranged that metal from either cupolas or blast furnaces could be used. Did you ever mix the cupola metal and blast-furnace metal in those works in preparing a converter charge?

A. If we could not pour from the direct-metal ladle sufficient metal to make up a converter charge, we made up the deficiency by tapping from a cupola or cupolas. The cupolas were arranged so that all could be tapped into a common trough, and under the spout

of this trough a ladle could be placed and then moved to a position in front of the converter to discharge its contents. This same track was the one used for the ladles bringing the direct metal from the blast furnaces. When the ladle containing the direct metal was received, the receiving ladle from the cupola was moved out of the way. The cupolas were arranged in a line back of and parallel to the converting vessel, and the ladle track was parallel to the same line and between them. The receiving ladle from the cupola could be pushed along on an extension of this track or switched off of it altogether, the ladles being handled by locomotives.

X Q. 71. You say that the plant was so arranged when rebuilt in 1886; did you use the direct metal about that time?

935 A. The direct metal was not used until quite a number of years after.

Redirect examination by complainant's counsel:

R. D. Q. 72. In the practice at Troy, how was the quality of the cupola metal determined; by analysis of the melted metal after it was tapped from the cupola, or by analysis and selection of the ingredients of the charge introduced into the cupola furnaces?

(Objected to as leading.)

A. The quality of the metal, so far as the component constituents were concerned, was determined by the analysis and selection of the materials charged into the cupola. The heat of the metal coming from the cupola was adjusted by the changes in the burden of the cupola; that is, the relation between the metal and the fuel charged into the cupola.

R. D. Q. 73. Will you state whether or not it was the practice to analyze the melted metal tapped from the cupola?

A. It was not the practice to analyze the melted metal tapped from the cupola.

R. D. Q. 74. Referring to your use of direct blast-furnace metal at Troy, will you state whether any disadvantages were experienced from tapping the furnaces as often as every two hours and 40 minutes?

A. It was found that tapping a furnace so frequently reduced the output per furnace very materially, probably over 10 per cent.

R. D. Q. 75. What were your official duties at the Troy works, in so far as they related to the operation of the cupolas and converters?

(Objected to as not proper redirect examination.)

A. In addition to my duties as chemist I had entire charge of the mixtures and was responsible for the quality of the metal produced.

R. D. Q. 76. What mixtures do you mean?

A. I mean the mixtures of the different kinds of metal and scrap and fuel charged into the cupola furnaces.

936 PITTSBURG, *June* 8, 1897.

William Metcalf.

WILLIAM METCALF, a witness produced on behalf of the complainant *in rebuttal, being duly sworn, testifies as follows* in answer to questions by complainant's counsel:

Q. 1. State your name, residence and occupation?

A. William Metcalf; Pittsburg, Pa.; consulting engineer and steel manufacturer.

Q. 2. Please state what experience you have had in the manufacture of steel in the iron-foundry business?

A. I was educated at the Rensselaer institute at Troy as civil engineer and graduated in 1858. That same year I entered the foundry business at the Fort Pitt foundry, Pittsburg, and remained in that business for about ten years. After the first year I was superintendent and manager of the plant and remained in charge until I retired from the foundry business in 1867. I then commenced the manufacture of steel as a member of the firm of Miller, Barr & Parkin, afterwards Miller, Metcalf & Parkin, proprietors of the Crescent steel works. I remained in that business as the engineering member of the firm until 1895. During that time it was my business to keep myself informed of all subjects connected with the manufacture of steel. I have written a large number of articles which have been published in the transactions of various engineering societies and technical journals, and I am also the author of a manual on the manufacture of steel published last year by Wiley & Son.

At present I am a member of the American Society of Civil Engineers; have served one term as a member of the board and in the year 1893 I was president of that society, presided for it at the congress of engineers at Chicago.

I am also a member of the American Institute of Mining Engineers; have served on the board, and was president of the society in 1880. I am also a member of the American Society of
937 Mechanical Engineers, and served one term as vice-president of the society. I am a member of the Engineers' Society of Western Pennsylvania, was the first president of the society, and for many years a member of the board. I am also a member of the British Institute of Civil Engineers.

Q. 3. What means have you taken to keep yourself informed as to the progress of the art of steel-making?

A. As the engineering partner of the firm owning the Crescent steel works, it was my special business to keep myself informed as to all that was going on in the steel world as fully as I possibly could. In pursuit of this branch of the business, in the year 1872, I visited Europe, with a view to learning all that I possibly could about the advances in Bessemer and Siemens-Martin, or what is now known generally as open-hearth steel, as well as to gather any information I could on the steel business.

I was well acquainted with Holley, Fritz, Jones, Fry, Forsyth,

Morgan, in fact practically with all the metallurgical engineers in this country and numbers of them in Europe. I kept myself well informed as to the processes and developments of these modes of making steel; also frequently talked over the subject with the engineers; read carefully all their reports, discussions, &c., that were published from time to time; had copies of Holley's reports, and knew generally what was going on in the steel world.

Q. 4. Are you familiar with the Jones method of mixing molten metal from the blast furnace, preparatory to its conversion into steel?

A. Yes, sir, I am familiar with the process. I also went over the Edgar Thomson plant with Mr. Jones once, when he explained the whole operation to me fully, and I examined it all with him.

Q. 5. Did you have any connection with the Fort Pitt foundry during the war, and with the manufacture of guns at that foundry?

938 A. I was superintendent and general manager, you might say, of the Fort Pit foundry all through the war, and had entire charge of the making of guns and of the purchase and preparation of iron for guns, the selection of iron.

Q. 6. Was your business at that foundry such as to give you an exact knowledge of the operation of casting the guns and of preparing the metal for the casting?

A. That was my special business. I bought the metal and prepared it, and cast the guns, and was responsible for the results. I was familiar with all of the details.

Q. 8. Will you please explain what was the practice in casting large guns, both as to preparing metal and as to running it from the cupola or from the melting furnace to the gun molds?

A. The first and necessary operation was to get the iron exactly right to make guns. To do that we had to visit the furnaces and the ore mines to assure ourselves that they had the proper ore there to make the kind and quality of iron that we required. After the iron was received by us, it was always carefully inspected by breaking sufficient of it to know exactly its condition. It was separated into the different grades in which iron comes from the blast furnaces, and then was ready for the first operation of melting.

In order to refine the iron somewhat and also to be able to work up the heads of the guns that we cut off from the rough castings, and to get a uniform material to mix in our furnace for casting guns, about three-fourths of the iron was charged in a furnace with certain proportions of gun heads (the scrap gun metal), it was melted and run out into the pig bed, just as is done at the blast furnace. Those pigs after they were run out we called our second-fusion iron, being iron remelted after coming from the blast furnace. Those second-fusion pigs were examined every day for their temper and piled up, graded out with great care, and then each day when the charge was made for a gun we had to use our

939 judgment in selecting the quantity of this second-fusion iron and the quantity of such pig iron as we had to use, in order

that the resultant cast might be of the proper uniform character for the guns, to give the tests required by the Government.

These charges were prepared and weighed very carefully at the furnaces, then melted, and then the iron was ready to be cast into guns.

Now the second part of the operation,—the preparation of the gun mold itself to receive this iron. In making a small gun, which required no more iron than one furnace would hold, the charge was simply mixed, as already described, the iron was melted in the furnace, and when ready was run into the gun mold and the casting was made. When the gun was larger and required the use of two or more furnaces, they needed a little different preparation on the floor for casting.

To illustrate this I will describe the casting of the first 20-inch gun that was made, which at that time was probably the largest single casting that had ever been made in the world. The mold for that gun was set in the pit used for containing the gun molds. Near that pit there was a little brick well built upon the floor, I suppose about five feet in diameter and 18 to 20 inches deep, lined with sand, and something in the shape of a saucer. From each furnace a runner was carried to this little well, and from this little well two runners were made to conduct the iron into the mold. The object of the little well was twofold—one was to check the flow of the iron coming down from the furnace to the mold in order that it should not run too fast and overflow, splash around the floors and in the beds; the other object was in case a furnace ran too fast this little well would enable them to hold back a little of the iron from the mold by the use of stoppers or tools they had for that purpose, so as to keep as near as possible uniform streams of iron running down into the mold. This was important, because if the iron
940 ran rapidly at one time and slowly at another, and more rapidly on one side than on the other, it was liable to cause a commotion in the mold and wash the dirt into the gun, making a dirty casting.

In casting the gun these preparations being made and the iron being all melted and ready, each furnaceman stood by his furnace at the tap-hole. When all was prepared the foreman directed one of them to tap his furnace, and this was done with great care, in order not to have a large rush of iron. As the iron came down and filled up the pool a vent was opened and the stream was allowed to run into the mold. After the iron had run some time in this way from the first furnace and it was evident that all was going well and there was no danger of a break-out in the furnace, then the second furnaceman would be warned to be ready, and at a signal he would tap his furnace, and the stream would come down into the same little well and there would be delivered over into the mold. About the time the first furnace was emptied or nearly so and the second furnace was being pretty well discharged, then the furnaceman at the third furnace was required to be ready, the order given and he tapped his furnace. So that for a few moments there might be part of the contents of the three furnaces running into this little pool at

once and being delivered over into the mold. Finally, the third furnace being empty and the mold filled, the gun was cast. That is a description of the operation of casting large guns, which was always used for any guns requiring more than the capacity of one furnace to deliver the iron required.

Q. 8. One of the witnesses in this case has said that at the Fort Pitt foundry during the war it was the practice to run the metal from several melting furnaces into a pool and from the pool to the mold, and that one of the objects of using the pool was "to try and get as near the same kind of iron in the guns." What have you to say to this statement?

A. I have nothing to say, except that that man did not understand the gun business. That never entered the mind of
941 anybody who had charge of the guns all the time I was there. The iron was mixed beforehand, requiring the most extreme care and skill to get it right to go into the gun, and after it was right and in the furnace the pool had nothing whatever to do with mixing the iron. It was a matter of mechanical convenience, as I have explained in the other answer.

The rough casting of that 20-inch gun that I described the casting of, weighed a little over 80 tons. We had something over 100 tons melted when we made that gun, for it was such an immense thing we wanted to be sure we had plenty of iron in case of accident in one furnace. I suppose that the pool, chuck-full, would hold maybe a ton or a ton and a half of iron, and in 22 minutes we ran through it more than 80 tons. You can get an idea for yourself as to whether there was anything done in mixing in running through that little saucer. It was a check, a convenience, in order to get the iron into the gun steadily and uniformly. In case of a rush of the furnace, we had a little chance to hold back there and get the iron away without scattering it over the floor. Sometimes a hole would break out in the furnace a little larger than the furnaceman intended; the metal would come with a considerable rush and it could be handled then until the rush was over.

Q. 9. Have you read Rodman's published description put in evidence by the defendant in this case, referring to the casting of guns?

A. The description of Rodman of the casting of two 10-inch Columbiads agrees exactly with the description I have given of the mode of casting the 20-inch gun. You will observe he says that one furnace was tapped first, and when the stream was considerably reduced by the emptying of the furnace, others were tapped subsequently, showing the same object precisely that I described for the
20-inch gun. That is, the pool was there to catch the iron
942 and enable them to be sure that, as each furnace came along, it was tapped properly.

Now as to the purpose of making the iron identical: There was a very lively contest between the mode of solid casting and the hollow casting of guns under the Rodman patent. Rodman, at that time, was a young lieutenant, without influence or means, but who believed thoroughly in his process. The proprietors of the foundry

agreed to cast a hollow gun and a solid gun out of the same iron, which they presented to the Government at less than cost, on condition that the Government would prove these guns to destruction, to determine which method of casting was the better.

When the casting was made it was important that there should be no possibility of saying that one kind was favored and the other not favored by the kind of iron that went into it, or the way it was melted or manipulated. So the two molds were prepared simultaneously and were arranged as described in Rodman's report. The iron was run from the furnaces into the pool, as described. It was taken in one runner out of the pool and afterwards divided into two, taken part to each gun, so that no one could claim either that the hollow gun was petted or that the solid gun was petted, but so that they were identical. That was the whole object of it.

You will notice that Rodman does not say anything about using that pool to mix the iron, but he does say that the iron in the two guns were identical, and that was the reason of it. There was a bitter contest between Rodman and his friends and the old conservatives who did not believe in Rodman's patent. Rodman conceived the idea that a gun cast hollow and cooled from the interior would consist of a series of concentric rings, each one pressing on the other from the outside to the center, bringing the compression of the metal and the strain in the gun in the best condition to
943 resist the force of the powder when the gun was in use. That was his theory, and it proved to be correct in practice, but he couldn't get his plan tried at all.

Finally, Mr. Charles Knapp, of the Fort Pitt foundry, said to him: "If you will transfer your patent to me absolutely, I will see that this thing is tried, and if anything comes of it I will divide with you the net profits that come from the royalties of the patent." The patent was transferred to Mr. Knapp, who first made a pair of 8-inch guns in a way similar to this 10 inch gun, and presented them to the Government at no cost. They were tried, and the hollow-cast gun beat the solid one all to pieces. All that I say now can be verified from the records. The result was so successful that the Government agreed with Mr. Knapp that they would pay, I think, 2 cents a pound for two finished 10-inch guns made in the same way. The 2 cents a lb. barely paid for the iron and the moulding. Then the pair of guns were cast that Rodman describes in the report that you have just read, and again the hollow gun was so incomparably superior to the solid-cast gun, that the Government adopted the Rodman method of casting guns. This is the history of the Rodman invention. The object in casting those guns together, and in running it into a common pool, running it out of this pool first in one runner and then dividing it, was so that no one could say one gun was petted or favored and the other one not; so, as far as possible, to make the iron in the two guns identical. That was the whole object.

Q. 10. Were you acquainted with Lieut. Rodman?

A. I knew Lieut. Rodman very well. I knew him from the time I went to the foundry until the breaking out of the war. Shortly

after the commencement of the war I was sent to the Watertown arsenal, and spent three months there making tests of iron to determine which irons were suitable for use in guns. At that time gun iron was produced in such small quantities that it would not begin to meet the demands of the Government, and it was necessary to find other iron that was suitable for guns. I spent three
941 months there testing samples as fast as they could be sent from Pittsburgh. At that time I was a guest in Rodman's family, was with him daily, and discussed the kinds of iron and guns, and all that sort of thing. Later I knew him all through the war during my charge of the foundry there. I frequently assisted him in his calculations and designs for his guns. I made the original drawing of the 20-inch gun already described, and it was afterward sent to Washington by Rodman, approved there, and the official drawing came back to us. The gun was designed in the Fort Pitt foundry, and I made the drawings and assisted Lieut. Rodman all through.

I also knew Maj. Wade very well, and was a sort of pupil and assistant of his, he being Rodman's predecessor in ordnance matters, a very prominent man, and well known as one of the leading ordnance officers of the country.

Q. 11. One of the witnesses for the defendant in this case, Mr. Durfee, testifies as an expert that the method of casting guns practiced at the Fort Pitt foundry of Knapp, Wade & Co., was substantially the same as the Jones method of mixing metals. What have you to say to this statement?

A. I know Mr. Durfee as a metallurgical expert, and as a man who was connected with the first efforts to make Bessemer steel in this country. My judgment is, from that answer, that Mr. Durfee is not familiar with the foundry business, and not very familiar with the Jones process.

Q. 12. Practically, what position does the Jones method of mixing hold in the art of making steel? What prominence is this method, as an original invention, recognized by metallurgists to have?

A. For some years previous to the development of the Jones apparatus and process, all the metallurgic world was crying out and studying and searching for the same method by which they could successfully and practically use the metal direct from the blast furnace in a Bessemer converter, to avoid the cost of remelting in a cupola and also the injury that the melting in a cupola does to the iron.

945 The object in using iron direct from the blast furnace in the Bessemer process, is twofold: First, quality, and, second, economy, or *vice versa* as people look at those things. All of the evidence of the literature of the Bessemer process goes to show that, for years there were serious efforts being made to devise a practical method of using the iron direct from the blast furnace, and to get rid of the serious trouble there is from the fact that a blast furnace is liable to change suddenly and produce an iron varying so much in silicon particularly, and also in carbon, as to cause very sudden changes in the working of the iron in the converter, rendering it

liable at one time to have the vessels and everything skulled up by a cold heat, or have everything burnt out and ruined by a too hot and wild heat. The whole object then was to get some mean of the product of the blast furnace which would avoid these extremes. These extremes did occur in practice, as the records show, and were such as to practically eliminate the benefit which it was well known would exist if the metal could be used directly from the blast furnace.

A great many methods were suggested and some patents were taken out for different ways of getting at this, but they were all practically failures, as evidenced in Holley's report of 1877, and in the general literature of the art. The matter really never was practically and thoroughly solved until Jones gathering up the accumulated knowledge of the art, organized it, and with great skill and genius devised the process which is now known as the Jones process. It practically eliminated all of these troubles and gave to the world a great advance in the art of manufacturing Bessemer steel.

Q. 13. Do you know whether, when the Jones process became known, it was recognized by others as having value?

A. Yes; I know from my general knowledge and acquaintance with engineers and from consultation with them, that the
946 Jones process was recognized as valuable and successful as soon as it was thoroughly well established.

Q. 14. What do you understand the Jones method to be?

A. I understand and know the Jones method to be, as described to me by Mr. Jones, and as I have often talked it over with engineers, a method which by the use of a large closed vessel he is enabled to take the metal from a blast furnace in successive portions, and by introducing it into this receptacle and heating it there a sufficient time, to produce not a uniform mixture of iron to take out of that vessel, but a mixture of iron which changes so slowly in its composition as compared with the sudden and violent change in the blast furnace, that he practically eliminates the difficulty in using direct metal, gives to his blowers a metal which they can handle and manage successfully from day to day, without producing skulls and cold heats on one hand, or overblown and wild heats on the other.

I would say this: That the clear advantage in the Jones method is this slow and minute change in the character of the metal, as against the sudden changes of the blast furnace; this being accomplished by putting successive charges into a large pool of metal and withdrawing it from a different portion of the pool, in such a way that the iron has some time to mingle and make a nearer average mean mixture than it would have if it were taken direct from the furnace to the blower, or if it was simply dumped into a huge vessel in whole taps and drawn out again and the vessel drained and carried off without time being given and care used to produce this averaging up and this slow changing of the composition of the metal. The slow manner in which Mr. Jones mixed his iron in this vessel, the time given it there, and the fact that

the tilting—or what would be the same thing—the rotating of that vessel, causes a motion in the iron and produces currents, which compel the different grades of iron to flow together, thus having a
947 tendency to produce a uniform mixture, are of importance.

As an illustration, from my own experience in connection with blast-furnace products, I know the sudden changes to which furnaces are liable, and the great difficulty such changes give us in the manufacture of guns, and the extreme care with which we had to watch the product of blast furnaces for that reason. For example, a blast furnace may be making a hard iron, nearly white; it may make its hearth half full of that kind of iron and change suddenly to making a very soft, open, grey iron. The iron running down into the furnace will flow on top of the first iron without mingling with it, until the furnace hearth is full and is ready to be tapped out. Then, when it is tapped out the hard iron will flow out first and run all over the pig bed and the soft iron will come afterwards and run all over the top of that, so that when the pigs are broken you can see distinctly a practically hard, close iron in the bottom half of the pig and a very soft, open iron in the upper half of the pig, with the line of demarkation clearly defined between the two kinds of iron.

Now, if iron can be produced in the blast furnace in that way and come out of it in that condition which I know it does do, and which I had to watch against constantly when we were making guns, one can easily see the great importance of the Jones method of pouring these irons from successive ladles, taking it out in successive small quantities, and tilting or moving the vessel, which makes currents and gives the iron time to mingle into a more nearly uniform product.

Q. 15. Would such a motion of the metal as you have mentioned in your last answer be produced if the vessel were made with a circular outline and the axis were in the center of the circle?

A. It would inevitably produce some current, some motion. You could not move a vessel full of molten iron, such as that, without causing disturbance and motion in the iron itself, because to
948 do that you would have to consider that you had the walls of that vessel absolutely smooth, perfectly circular and frictionless; also that your metal was perfectly frictionless, so that in revolving the vessel around the metal the metal itself would remain quiescent. That is a theoretical mathematical statement which could not exist in practice. It is utterly impossible. You could not make a vessel that was absolutely frictionless, absolutely circular and absolutely hung on the centre so that it would be possible to revolve it without disturbing the molten metal, which is a liquid mass inside. It must produce some disturbance and some current. Any motion, it does not need to be violent, must continue through the metal, and even a little variation of temperature in the centre of the mass would cause a circulation, and that circulation would carry the elements as they are contained and mingled, all through and diffuse them more uniformly. You cannot move the vessel without moving the mass inside.

If you *you* take a glass tumbler full of water with a piece of ice in it, and move that tumbler around a number of times, you apparently do not move the ice, because it apparently does not revolve with the tumbler, but if you watch carefully you will see that the ice always does move. There always is some friction, but by making a quick motion the lump of ice does not appear to follow nor the whole mass of water to follow the tumbler—which it could not do unless the friction were sufficient to make it one solid mass, but by watching closely you will see that both the water and ice do move. Now, take a vessel of molten iron and you cannot rotate it without disturbing the iron inside. To claim otherwise would be utterly absurd.

Q. 16. The bottom of the mixing vessel is rougher than the surface of the glass in the tumbler would be?

A. Yes, sir; and the adhesion is greater. Any claim that the tilting would produce no currents is a mechanical absurdity.
949 It does not require a violent motion to mingle these metals, but any motion will start a current, and keeping the metal in motion will mix the metal.

Q. 17. Will you please explain a little more fully the advantage of the Jones method in avoiding the contamination of the iron which results from remelting in a cupola furnace?

A. On the matter of the injury in melting iron in a cupola I will say that during the war, when we were rushed by the Government for both guns and projectiles, we were allowed by the Government to cast our projectiles from our cupola furnaces because the demand for guns required every particle of our capacity in the air furnaces. We used for making projectiles what was known as the Hanging Rock iron, known all the world over as of exceedingly high quality and good iron for foundry and machine purposes. The average strength of the projectiles, as shown by test specimens made of this iron from the cupola, was about from 21,000 to 23,000 pounds per square inch. Toward the close of the war, when the great rush was over, Rodman demanded that we should make the projectiles of a material that would have at least 25,000 pounds strength. After considerable discussion we considered the question as to which would be cheaper—to buy an exceedingly high-priced gun iron and melt it in a cupola to make projectiles in the hope of getting this 25,000 pounds, or whether we would melt the material in the air furnaces, of which we now had a surplus, and use the same material and see whether it would bring the product up to the requirements of Rodman. We decided that the difference in cost between melting in a cupola and an air furnace was less than the difference in cost of a high-priced gun iron and the ordinary Hanging Rock machinery irons, all of these irons being known as charcoal pig iron. We then charged the air furnaces with identically the same class of iron that we had been using in the cupolas, cast our projectiles in that way, and the test at once arose to 26,000, 27,000 and even
950 28,000 pounds, showing the practical difference of about 5,000 pounds in strength between the cupola and the air furnaces;

in other words, that the use of the cupola reduced the strength of that iron about 20 per cent.

It is stated, and always has been stated by the prominent engineers in the world, and may be seen in the reports and discussions of the societies and institutes, that the melting of iron in a cupola for the Bessemer process injured the iron. There can be no doubt in my mind, from my experience with hundreds and perhaps thousands of tons of iron, with the results which I have just given, that that statement is correct; that the melting in a cupola does injure the iron, reduces its quality from what it is when it comes out of the blast furnace.

Q. 18. Have you read the testimony of defendant's witnesses with reference to the operation of the Whitney foundry in Philadelphia, and the foundry of the Taylor Iron and Steel Company at High Bridge, N. J., and do you understand the practice which they have described?

A. I understand it fully. I know the Whitneys very well, and was in their foundry a good many years ago. I have a large experience of my own in the manufacture of chilled rolls and chilled dies, and some car wheels to a small extent, so that I understand pretty fully the processes and their objects.

Q. 19. I wish you to state whether the use of the ladle before the cupolas in these foundries is substantially the same or substantially different from the Jones method, and whether or not the same would suggest the Jones method to the skilled steel-maker.

A. I do not think they have the slightest relation to the Jones method. I do not think they would suggest the Jones method to anybody. I do not think that the object in using them ever had any relation to the results produced by the Jones method, and for this reason: From my own experience as a foundryman, I
951 know it is the common practice and always has been the practice, first in charging furnaces for any purpose to select the iron with great care before it is put in the furnace, whether it be a cupola or an air furnace, to produce an iron desired in the casting to be made. That is always done by any foundryman who knows anything about his business and has any regard for the character of his work.

The use of a large ladle in front of a furnace is a common, obvious practice, for convenience. If, in the cupola, for instance, it is desired to melt a considerable number of tons of iron for one large casting, a much larger weight of iron than the hearth of the cupola itself will hold, then the obvious and simple thing to do, and what every foundryman does do, is to set under the nozzle of the cupola a ladle large enough to hold the charge that he wants. He starts his cupola and when his hearth is melted full he taps that iron into his ladle, and when the slag shows he stops off the tapping hole, running no risk in having any difficulty in stopping off his iron, and when the furnace fills up again he taps again in the same way, until finally he gets into his ladle the amount of iron he wants to make his casting. That he carries away and pours into the mold.

Suppose the reverse to be the case: that he has 10 or 15 or 20

tons of iron to melt in an afternoon, which he is going to cast into 200 or 300 little castings, a great many of them perhaps to be poured from what they call a hand ladle—a ladle small enough that one man will carry it in his hands to the castings. Now, if he intends to melt that quantity of iron in his cupola and tap it from time to time into these innumerable little ladlefuls, he will inevitably, or almost inevitably, have one of two things happen. He will either, by the continued prodding at the tap-hole of his furnace have it crack away and the whole contents of his furnace come out with a rush and be dumped on the floor, or in stopping the stream of iron so often against that tapping hole he will accumulate
952 a little iron in there until finally he fills the tapping hole with a plug of hard set iron, and he cannot tap his furnace or open it. Sometimes he may knock hard enough with a sledge to drive a bar through and discharge his furnace, but more often he has to let his whole furnace bottom drop—drop all of the fuel, iron and everything on the floor and start over again. These are things I have seen happen over and over again. When a man gets a little careless in the use of a cupola or an air furnace the same thing applies.

How do they avoid that? They take a large ladle and when the furnace has melted its hearth full they tap it out into the ladle, stop off as soon as the slag shows and go on melting. Now this ladle can be tilted and they take the shanks full as they want, large or small, the moulders come forward and take the iron around and go on making their castings. They keep that up all afternoon, the furnace is going on steadily producing that iron, and he is tapping his furnace right because he is using the proper means to do it.

You can understand from this description that to attempt to tap out these successive charges from the furnace in one case, or in the other to attempt to hold five or six times as much iron in the furnace as the furnace will hold, would be an absurdity. You can see that the use of the ladle is a simple mechanical contrivance for convenience, known to every foundryman in the world, and used the world over. There is no reason why it should suggest the Jones method or anything else but just what it is.

Now, to bring that to the Whitney practice in making car wheels. Whitney describes three large cupola furnaces. I would call your attention to the fact that he first describes that the iron was selected with the utmost care in ton charges, 1,000 pounds of this, 500 pounds of that, 200 pounds of another, 100 pounds of another, and even 50 pounds of another. These are mixed in ton charges and charged into the furnace on a bed of coke; then another bed of coke
953 and then another ton of charge, etc., in doing which Whitney does exactly what we always did in the Fort Pitt foundry, exactly what we did in making guns, exactly what we did in making chilled rolls or dies, and occasionally car wheels; to get his iron right before he got it in the furnace, with the utmost care.

Now, so far as there is any comparison, that is a simple description of what the original Bessemer process was, where they bring the iron to the cupola and charge it in in successive charges, se-

lected with reference to the quality of the iron and run it out in a ladle. That is the common foundry practice, and that is what Whitney did. Now, when it comes to the large ladle that Whitney used, it did not involve any thought in regard to the Jones process for when that was invented the Bessemer process was hardly known. Then it could not have been a thought in Whitney's mind at all, and there is an obvious reason for that: Here are three furnaces, he wants to melt 15 or 20 tons in each in the afternoon, altogether, say 50 or 60 tons of iron. Now, if he puts down in front of each cupola a ladle sufficient to collect the iron from that cupola, to be poured again into smaller shanks to make the successive car wheels—which he would have to do in any case if he had only one furnace, as I have described, you see if he put a ladle in front of each furnace he involves then an extra man at each furnace to handle that ladle and deliver the iron into the shank. He has three ladles to keep up and to care for, and three places where the men have to crowd in together to get the iron. Now, by putting a large ladle where he can reach it from all three and tapping the iron from each furnace into this large ladle and having it handled by power, one man handles what in the other way at least three men would have to do, and certainly if he didn't use power it would have taken six men to his three cupolas. So that, under the best circumstances he saves two men, and under ordinary circumstances, five men's time every day by bringing it into this large ladle and handling it by steam power.

954 Now he had another advantage; his iron is carefully and properly mixed beforehand. If he hadn't done that he would simply have been an ignoramus. Then the only advantage that I can see in the Whitney process is simply the mechanical ones I have given, and possibly enabling the metal to be cooled down to the exact temperature necessary. I cannot see where that process could have led up to the Jones method, especially as the foundry practice was devised and invented before the Bessemer process was well known. That was simply an old foundry practice brought up by engineering care and skill, and Mr. Asa Whitney, the old gentleman, was a skilled mechanical engineer. It was simply a slight advance in the art of founding. That is all there was in it.

Q. 21. What importance, if any, do you attach to the uniformity of temperature such as may be gained by the use of the Whitney ladle and such as is gained in the Jones mixer, and what value is the uniformity of temperature in either case?

A. In the Bessemer process, sudden and violent fluctuations in temperature are liable to cause almost as disastrous results as sudden and violent changes in composition,—perhaps not quite as disastrous because different temperatures can be handled by a very skillful blower so that he may produce a merchantable result, but not so good a result as he would by having his iron even in temperature.

The Jones mixer has the advantage in the Bessemer practice of equalizing or making more uniform the temperature of the charges from the different blast furnaces, one hot and one cold and one

medium, so that the changes in the iron as it goes to the converter are minute, gradual and such as the blower can see and handle without difficulty, so that while he may work from a quite low temperature to a very high one he may still produce good results if the change is gradual, such as he can see from heat to heat.

955 In what you have called the Whitney process, which is the common foundry practice of all the world, there is no such necessity and could be no such advantage in a gradual change of temperature even if it were produced, for the fact is that in making a chilled casting the operator is doing actually the same as a steel worker does when he hardens a piece of steel by the well-known method. Now in either case the necessity to secure a good result is not what you would call a uniform temperature or average temperature, nor a temperature changing gradually from high to low, but it is an absolute fixed temperature. It is impossible to cast good car wheels or to harden steel properly except at one fixed temperature for each composition of the metal. If it be too cold, there is a bad result in one direction, and if it be a little too hot there is a bad result in another direction. Therefore, the uniformity of temperature and the slow changing temperature which are so valuable in the Bessemer process, have no use whatever in the foundry process. The foundryman in fact gets his iron out of the furnace at least a little hotter than he wishes to pour into the mold and then waits for a moment before it comes to the right temperature.

Q. 22. Have you read the testimony of Robert C. Totten, one of the defendant's witnesses in this case, and if so, will you state whether the practice at the Fulton foundry which Mr. Totten describes has any relation to either the Jones method or the mixing of iron for the purpose of securing homogeneity?

A. I have read the description of the practice at the Fulton foundry. I see no connection whatever between that and the Jones process, nor anything that involves any idea of mixing metals for the purpose of securing homogeneity.

As I understand the description, the fact simply was that their air furnace would not hold enough iron to make the large roll that they had in hand, and to complete the mass they had to melt

956 the necessary quantity in their cupola. In order to get this iron all into one mass so as to be able to cast a roll in the continuous stream necessary in making any casting, as the cupola iron was melted they poured that into the same large ladle until they had sufficient quantity to make the casting and then they made it. Any foundryman would do the same thing under the same circumstances and would hardly conceive of any other way of doing, as it seems to be about the only practicable method. It was in common use at the time and at all prior times so far as my knowledge of the foundry business goes.

Q. 23. Have you read pages 14 to 20 of Edward Kirk's book on the Founding of Metals, published at Sharon in 1879; if so, will you state whether it describes any method or any mixing of iron analogous to the Jones method or suggestive of the same?

A. I have read the remarks of Mr. Kirk with reference to the ad-

vantages to be gained in running cupola charges into the ladle and from there getting the iron for making castings, where he claims there is some advantage in mixing in a ladle. I see nothing in that at all that could possibly suggest the Jones method, and largely for the reason that what Kirk describes is what every foundryman does, and I believe always has done, in the making of castings, more particularly as a mechanical convenience. As I have stated before in reference to other foundry practice, this matter of pouring into the ladle and using the metal from that ladle for making castings was a common, obvious and convenient way of handling the products of the cupolas.

As to the matter of mixture, I never knew of any foundryman who had any regard for the character of his work, that did not carefully select and mix his irons before they were charged into the furnace, whether that furnace was a cupola or a reverberatory furnace. As to the matter of mixture, it is a very simple principle of the law of liquids that two liquids when poured together into a common receptacle will give a resultant liquid which is not quite
957 identical with either, assuming that the two liquids were not identical in the first place, but this simple fact would not necessarily lead up in any way to the Jones method, except that it is one of the simple physical laws that any man in Mr. Jones' position would make use of as he would all other facts within his knowledge in designing either the process under discussion or any other process.

Q. 21. Historically, what had the use of ladles or cupolas in the foundry practice to do with the development of the Jones method?

A. It had nothing whatever to do with it. The ordinary use of ladles for collecting the iron melted by the cupolas is, as far as I know, as old as the foundry practice. What was known in Bessemer practice as the Holley intermediate ladle was substantially the application of the old foundry practice.

This was the condition of things until it became obvious to the Bessemer people who had blast furnaces near their converters, that if they could use the metal direct it would save the cost of the use of a cupola and also the injury that the cupola does to the iron, and then they began to cast about for a way to overcome the difficulty. But the use of the ladle did not suggest anything necessarily to anybody, because that ladle was a matter of common knowledge to every tyro in the foundry business the world over. If such engineers as Holley, Kennedy and Hunt, and all the bright and able minds that were engaged in the business, could have followed logically and by analogy from the ladle to the Jones mixer, some of them, or all of them, would certainly have done so. You can see that their minds were on it and that for years they were struggling for it. Holley was traveling in Europe and watching the process and he writes in his report of 1877 that it is practically a failure, there is nothing over here that we can use.

Then Jones goes to work and does accomplish what all
958 these men have failed to accomplish; does it in a very skillful and ingenious way, and all the world [illegible]nce acknowledges

the success and usefulness of his invention. Where the connection or analogy comes in between the old cupola practice, the old foundry practice, and the Jones method, is difficult to see, because all of these engineers were, as engineers, quite Jones' equal in general intelligence and knowledge of their profession, and they had their whole minds on it. It was particularly Holley's whole business. Holley, Kennedy and Hunt all of them were at it, and all Jones' peers as engineers, but none of them reached it or saw it.

As I believe I have stated before, the use of this intermediate ladle, both in the foundry and in the Bessemer practice, was an obvious convenience and a practical necessity because there had to be some way to take the iron away from the cupola as fast as it melted a hearthful; and if the cupola did not hold enough in its hearth to make in one charge the desired casting or the desired charge for the converter, then it was necessary to put that iron somewhere and keep it until the cupola could melt another and another, and until sufficient iron was received. So that the whole process is a simple, obvious, mechanical operation, a convenience and necessity. It was well known to every engineer, and it is hardly possible to conceive how it had anything to do with leading Jones' mind up to his method, when it failed to lead any other mind to anything like the same method.

Q. 25. Some of the witnesses for the defendant in this case have said that the practice of using in the Bessemer works a ladle larger than a single converter charge for the purpose of receiving the melted iron from the cupola and delivering it to the converter, was substantially the Jones method of mixing. Do you agree with them in this?

A. It is really and practically nothing of the sort. The well-known Bessemer cupola process is up to the converter nothing more or less than the well-known and time-worn foundry
959 method of handling cupolas. The fact that there is a residuum often in the ladle has nothing to do with uniformity of temperature or mixing of metals. The use of a ladle larger than the charge is simply the common sense use of his ladle by every foundryman. For instance, if a man wants to make a 300-pound casting he will run the iron into his 300-pound ladle, but that ladle if filled brimful will hold 500 pounds probably. If he wanted to make a 5-ton casting he would run the iron into what he would call his 5-ton ladle, but that ladle running brimful would certainly hold six tons or more, likely seven tons. No man experienced in the art and possessed of common sense would ever think of using a ladle which would only hold brimming full the charge that he wanted to use. The handling and carrying around large masses of molten metal is no trifling matter on account of the danger of spilling, and consequently burning and killing of workmen.

Q. 26. What have you to say as to the desirability of using a gas furnace as an intermediate vessel for receiving and preparing the blast-furnace metal for use in the converter as suggested in Durfee's paper put in evidence by the defendant?

A. From my knowledge of the use of a gas furnace for melting and holding cast iron, and from my knowledge of the cost of operation, and the necessity for having skilled labor of a very high order to take charge of and manipulate such furnace, my judgment would be that it would cost more money than it would to run the iron into the pig bed and remelt it in cupolas. Furthermore, the changes would go on in the metal persistently while in the open-hearth furnace, and would tend to destroy all the advantage that could possibly be had by the mingling of the iron in such large furnace. To hold the iron in such furnace without change of composition even for a few hours requires the skill and judgment of a person thoroughly trained both in the practice of the furnace and the chemical knowledge of the materials. Further in Mr. Dur-
960 fee's papers he makes it plain that it was his intention when he received in the furnace iron which was not of proper composition for blowing, to remedy it by additions of such other metal of varying composition, and melting it in with the charge, as would bring the whole batch up to the desired condition. This again involves a great deal of time and expense and as high skill as is necessary in the manipulation of an open-hearth furnace to produce open-hearth steel. Where there could be any possible advantage is Mr. Durfee's method I fail to see.

Q 27. What have you to say as to the desirability of putting blast-furnace metal into a furnace and keeping it hot by introducing a small amount of flame over a large surface of the metal?

A. My answer to the previous question covers all the difficulties that I see in this suggestion made by Mr. Holley. It would be impossible to subject a great surface of molten metal to the action of a flowing flame without continuously changing the character of that metal by the well-known reactions of the open-hearth steel process. To hold that metal even for a few hours without serious change, would involve the highest kind of skill and necessarily quite as much expense, if not more than is involved in taking the iron to the cupolas and remelting it.

Q. 28. Some of defendant's witnesses in this case have called the Jones mixer a reverberatory furnace. Are they correct in so doing?

A. I cannot compare such statement, as it is a wrong use of language. What is known in the art as a reverberatory furnace is a distinctive machine for certain purposes. We might say that in this respect the name reverberatory is *is* a shop term, that every shopman knows when a reverberatory furnace is spoken of what is meant by the speaker. To call the Jones mixer a reverberatory furnace because it is possible to insert in one end of it a gas pipe to warm it up a little, is as far away from the correct use of the
961 words as it would be to call this office a reverberatory furnace when you light one of those electric lights.

As to the right to use a shop term and to use it as a distinct technical term with a special meaning, I would say that this is a common practice in all arts, and in my manual on steel will be found quite a lengthy glossary of shop terms, which are given there because

some people not entirely familiar with the art of handling steel may not understand the use of the terms in the book if they attempt to get the meaning from the ordinary dictionary meaning of the word.

Q. 29. Have you read the various patents and publications which have been introduced in evidence by the defendant in this case, and if so, will you state whether there is anything in them which describes the Jones method?

A. In my careful reading of all of these discussions at the time they were first published and from my knowledge of the practice at that time and subsequently and up to the time of Jones' invention, I should say that there was nothing that ever suggested to me, or I think, would suggest to any engineer the designing and carrying out of the Jones method. There was a great want in the Bessemer world and a great variety of suggestions, but nothing practical and nothing leading up to the Jones method.

PITTSBURG, *June* 9, 1897.

Met pursuant to adjournment.

Present: Counsel as before.

Cross-examination by defendant's counsel:

X Q. 30. What Bessemer works have been controlled or superintended by you, and during what periods of time?

A. I was the originator of the Pittsburgh Bessemer Steel Company, and one of the owners, until we sold out to Carnegie, although I was not a superintendent of that works. I built a Bessemer plant at the Crescent steel works, and was in charge of that plant as long as we used it.

962 X Q. 31. What was the capacity of these plants, and during what years were you connected with them?

A. From memory, the Pittsburgh Bessemer plant had two 5-ton converters, we ran it something less than two years. I do not remember the years, it was in the eighties. I can't fix the date of the Crescent plant, it was somewhere about 1890. The Crescent plant had two 3-ton converters. We ran that about six months. We abandoned the use of it and adopted the basic open-hearth practice, as being better for our purpose.

X Q. 32. What experience, if any, have you had in the manufacture of Bessemer steel from molten blast-furnace metal direct, either with or without the mixer?

A. None at all.

X Q. 33. Have you read the Jones patent in suit?

A. Yes, sir, I read it over.

X Q. 34. Have you read the companion patent of Jones on the apparatus illustrated in the patent in suit?

A. I think not; I believe I have read only one patent.

X Q. 35. Are you aware that there are two Jones patents of same date, one that in suit, and the other for the details of the apparatus shown in the first patent?

A. No, sir; I have no recollection of ever seeing the second patent.

X Q. 36. Referring to the patent in suit, how many processes do you find described therein as the invention of Jones?

A. I only read the patent over casually, and therefore I can't answer that question.

X Q. 37. You speak in answer 14 of the Jones process including "the use of a large closed vessel." Do you understand that the top or cover of the vessel is an essential feature in working the Jones process?

A. From my experience in handling melted iron and steel, I should say that the use of the cover is so important as to be practically essential.

963 X Q. 38. Is a charging ladle a closed vessel, such as you refer to in answer 14?

A. None that I ever saw.

X Q. 39. Mr. Jones says in his patent "My invention may be practiced with a variety of forms of apparatus—for example, by merely receiving in a charging ladle a number of small portions of metal taken from several ladles or receiving vessels containing crude metal obtained at different times or from different furnaces, the mixing being performed merely by the act of pouring into the charging ladle, and other like means may be employed." Had you this statement in mind when you testified that his method involved the use of a large closed vessel?

A. I think not. I had in mind, when I made that statement, the apparatus and the process as shown to me by Mr. Jones.

X Q. 40. For what purpose is the lid or cover used on the large Jones mixer?

A. To prevent rapid radiation of heat from the metal.

X Q. 41. I will ask you, as a skilled engineer and metallurgist, to assume that an open-topped vessel is provided to receive and hold until required molten metal, and that it is found that there is an excessive loss of heat by radiation. Would it, in your opinion, require invention, or anything more than the exercise of the skill and judgment of the engineer, to close the top in order to prevent that loss of heat?

A. I don't know that I am sufficiently well informed as to the difference between ordinary skill and invention to give a proper answer to that question. The necessity for some means to stop that radiation would appear in that case to be obvious.

X Q. 42. Well, leaving the question of invention out of consideration, what would be the obvious method to you, as an experienced engineer, to prevent the loss of heat by radiation from molten metal in an open vessel?

964 A. I have seen various methods used by applying coke dust or fine charcoal, or even dry wood to the surface. I don't know that I ever saw a cover applied in that way until I saw the Jones mixer.

X Q. 43. You had seen covers applied, however, to prevent the

loss of heat, to ordinary domestic kettles, boilers, to crucibles and other vessels, had you not?

A. I have seen covers applied to all such vessels. I suppose in some cases to retain the heat, but in crucibles they have far more important use.

X Q. 44. Previous to the introduction of the Jones process, many millions of tons of steel had been made by the direct process without the use of either the cupola or the mixer, had they not?

A. I believe a great deal of steel had been made that way. I can't say whether there were many millions of tons or not.

X Q. 45. And many steel works are still using the direct-furnace metal in different parts of the world without the mixer, are they not?

A. It is quite probable they are; I have not noticed in the technical journals any special reference to that for several years.

X Q. 46. I will ask you to read that part of the Jones patent referred to in Q. 39, which you did not have in mind when you originally gave your definition of the Jones process, and will ask you, in the light of this matter, to again define the Jones process as you understand it and as you undertook to define it in answer 14.

A. I would say that my previous definition of the Jones process would stand, and that the mode of mixing in an open ladle described there is one which Mr. Jones includes in his patent although he prefers the closed mixer, as I certainly would if I were going to use the process.

965 X Q. 47. Then the Jones invention, as you understand it from the patent, includes the mixing of the molten metal in an open, as well as in a closed vessel, does it?

A. The patent clearly says that it may be practiced that way.

X Q. 48. Am I not correct and fair in saying that Mr. Jones treats the open charging ladle and the closed vessel as equivalent structures for accomplishing his end, or to use his own language as apparatus by which "my invention may be practiced"?

A. Not in my judgment. He says distinctly that he prefers the closed vessel.

X Q. 49. But he does say, does he not, that his invention may be practiced either by the charging ladle which you say is open or by the large closed vessel shown in the drawing?

A. I so understand it as we have read it in the patent.

X Q. 50. In stating the advantages of the Jones process, I understand that you compare it more particularly with the old direct-metal process. Am I correct?

A. I compare it in my mind with the well-known troubles that were had all over the world in using metal direct, all of which troubles were practically overcome by Jones' process.

X Q. 51. The troubles in the old direct process were due mainly to the fact that the furnace cast was run into a series of ladles successively, and that the temperature and composition of the metal in these ladles varied widely. Is this true?

A. My knowledge of the direct process is entirely that gained from reading carefully all that came within my reach in the technical

journals and transactions of various engineering societies. I judge that you have described in your question some of the important troubles that have been met.

X Q. 52. And the variation in the metal in the successive ladles from the furnace was due mainly to the fact that the furnace metal at different levels varied in temperature and in the silicon content?

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A. I so understand it.

X Q. 53. Now in the old direct process I understand that these furnace ladles containing metal of different temperatures and compositions were emptied into the converters one at a time, so that one converter charge might differ widely from another. Is that correct?

A. From my reading that was practiced, I believe, in some cases.

X Q. 54. And the real pith of the Jones process lies in the fact that these ladles of variant metal are mingled or combined, so that he obtains a mean or average metal suitable for conversion?

A. I don't understand that to be the pith of the Jones process at all. As I understand it he secures inevitable changes in composition and temperature by such small increments from charge to charge as to make it easy and practicable to produce good uniform work from the converter.

X Q. 55. How would this apply, as Jones states his invention is intended to apply not only for metal for use in connection with converters, but in connection with "casting the metal from mixing vessels into pigs for use in converters, puddling furnaces, or for any other uses to which pig iron may be put in the art"?

A. For such uses the pith of the process would certainly be the obtaining of a nearly uniform average composition.

X Q. 56. Now coming back to the pith of the Jones method, what does Jones actually do other than to mix or mingle together portions of furnace metal which differ from each other so as to get a mean or average metal. What else is there in his process that controls the composition or the temperature of the resulting mass?

A. That involves two answers. In the first part he gets in addition to the mean of addition minute increments or decrements of composition and temperature, so that the metal delivered to the converters is not confusing to the blowers. There is nothing in his process which controls the temperature or composition beyond the mingling.

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X Q. 57. In the Jones process as you have treated it, the furnace casts are run out into a series of ladles which are then emptied into the mixer or reservoir, so that the variant increments are mixed or mingled into a homogeneous mo*l*ten mass. Now assume that instead of dividing the furnace metal by ladles the same metal should be run in an entire cast or casts into a common vessel from the same furnaces; you would then have in this vessel, would you not, the same composition as in the first instance?

A. First, I have not stated anywhere that any of the metal is homogeneous Next, in your said operation you would have the

same number of pounds of iron, carbon, silicon, phosphorus, sulphur, manganese, or whatever other elements might be in the iron, but they would not necessarily bear the same relation to each other in the mass.

X Q. 58. Do you wish the court to understand you as saying that if you deliver certain metal from a blast furnace into a receiving vessel by a succession of ladles, that you would have a different chemical composition or a different body of metal from that which would be obtained by delivering the same metal from the same furnace at one operation into the same vessel, the mass being permitted in each case to remain in the vessel in which it is placed?

A. If the mass remained in the vessel quiescent an indefinite length of time, the time necessary not being known by me at all, by the well-known law of diffusion of metals, the mass would become, I should judge, practically the same in either case. If the two supposed masses were allowed to cool down rapidly to the solid condition, the cold masses resulting would be found very different in physical structure.

968 X Q. 59. Can you pour molten metal into a vessel from a ladle or from a runner, or by any other means, without causing an agitation and circulation in the mass?

A. No, sir.

X Q. 60. Is it not a fact, that whenever molten metal is permitted to remain in a stationary vessel, there is a constant circulation within the mass due to changing temperature at the surface or other causes?

A. I believe there is to some extent until the metal sets.

X Q. 61. You have referred to the Jones process as involving the addition of "minute increments" of molten metal to the mass. Will you define for the court your meaning of minute increments?

A. I never made any such statement at all.

Question withdrawn.

X Q. 62. What do you mean in answer 56 by "minute increments or decrements of composition," as applied to the Jones process?

A. I mean by minute increments or decrements such a change in composition as would cause a variation in successive converter charges so small that the change would make no practical difficulty in blowing the metal, while the blower might observe the same, if it would be such as he could easily provide for in blowing and cause him no trouble.

X Q. 63. But you have had no practical or actual experience in dealing with these variations in the direct-metal practice?

A. No, sir.

X Q. 64. The important variation to be guarded against in Bessemer blowing is mainly in the percentage of silicon, is it not?

A. Yes, in composition, as I understand it.

969 X Q. 65. Now what are the limits of variation between one converter charge and another, within which one becomes of material service in determining the blower of the next?

A. As I said before, I never blew any direct metal, and I would rather not try to answer that question, as I could only quote Mr. Gayley or other experts, who could answer it so much better than I.

X Q. 66. Can you say from your own knowledge what the average variation in silicon is under first-class blast-furnace practice at the present day?

A. No, sir.

X Q. 67. Can you say of your own knowledge what the extremes of variation are in the silicon content of the mixer metal during a day's operation?

A. No, sir.

X Q. 68. Can you of your own knowledge give the court any idea whatever as to the variation in the silicon content between the ladles of mixer metal as they are taken successively to the converter at the Edgar Thomson or other works?

A. No, sir.

X Q. 69. Am I correct, Mr. Metcalf, in my understanding that as to the actual variations and percentages under the direct-metal process and under the Jones mixer process, you are dependent on other persons, or on publications, for your information?

A. Yes, sir.

(Counsel for defendant here gives notice that he will at the proper time move to strike from the record all portions of the deposition of this witness in any manner dealing with the direct-metal practice or the Jones process and practice thereunder, as hearsay and incompetent, the cross-examination being continued without waiver of such notice.)

(Counsel for complainant insists that counsel for defend-
970 ant shall specify particularly the specific questions and specific answers to which his objection and notice are intended to apply.)

(Which defendant's counsel agrees to do in due time.)

(Counsel for complainant insists that he has a right to *to* know what answers are objected to before proceeding with any redirect examination, and if this request is not complied with he shall move to strike the objection and notice from the record, as it is well-known practice that objections to the testimony of witnesses made on the record must specifically refer to the questions or answers objected to.)

X Q. 70. In stating the advantages of the Jones process, as compared with the prior art, did you take into consideration any prior direct process other than one in which the furnace metal was run into ladles from the furnace, and these ladles of metal delivered to the converters without being mixed or mingled?

A. I will state generally that I knew, before the Jones process was invented, about the Terrenoire practice, the Creusot practice, and the practices in England at Bolckow, Vaughn & Co. I also know of the statements of such men as Windsor Richards and Mr. Snelus, and other eminent European metallurgical engineers, and

also of the contents of Holley's report, so that I supposed I had officially a general knowledge of the condition of the art both before and after the introduction of the Jones method.

X Q. 71. So far as your practical experience in Bessemer blowing goes, whether of cupola or direct metal, or mixer metal, how near must the percentage of silicon in one converter charge come to that in the next charge, in order to be a substantial aid or guide in the blowing of the second?

A. In our practice at the Crescent steel works, it was necessary to keep within about .2 of 1 per cent., or else we were liable to have serious trouble, which in fact we did have.

X Q. 72. Suppose that a second converter charge was liable
971 to run either 25 per cent. above or 25 per cent. below the succeeding charge in the amount of silicon. Would that first charge be any substantial guide to the blowing of the second?

A. In our little practice at the Crescent works, such a change would have played the mischief with us. I cannot answer as to a 10-ton converter, I have no practical experience with a 10-ton converter.

X Q. 73. Suppose the silicon variation between one converter charge and the next was 50 per cent. in amount; would one charge, in your opinion, be any reasonable guide to the blowing of the next, either in a large or in a small converter?

A. I decline to give any opinion about a large converter as I never blew one. It would be no guide in a small one.

X Q. 74. Can you give any answer as to the effect of the 25 or 50 per cent. variation in silicon based on your technical reading?

A. Based on my technical reading, I should judge that a variation of 50 per cent. would be disastrous.

X Q. 75. Based on your technical reading, would the variation in the amount of silicon up or down to the extent of 25 per cent. admit of one charge being used as a guide for the proper blowing of the next?

A. I should judge that such a variation would be very troublesome.

(Complainant's counsel objects to all questions which have or which may be put in cross-examination of this witness relating to the patent in suit, because it is not cross-examination.)

X Q. 76. Have you witnessed, at Edgar Thomson, the practice of what you understand to be the Jones process?

A. Yes, sir. I went over the plant one day with Mr. Jones, when he showed me the whole operation and explained it fully.

972 X Q. 77. At Edgar Thomson, the additions to the mass of mixer metal are each about one-eighth of the capacity of the mixer vessel, are they not?

A. Yes.

X Q. 78. At the Edgar Thomson works, it is the practice, is it not, to deliver the ladles of blast-furnace metal to the mixer as soon as possible after they are drawn from the blast furnace?

A. I am not at all familiar with the daily practice, and therefore I could not answer that.

X Q. 79. Are you aware that at Edgar Thomson it is the practice to exclude part of the blast-furnace metal when running very bad from the mixer and to run it into pigs, which have to be remelted?

A. I would gather that from some of the testimony I have read. I will say I do not know it from my own knowledge.

X Q. 80. If, instead of drawing a furnace cast into successive and separate ladles, which would contain metal differing in character, the entire cast should be drawn at once into a single vessel and there permitted to mingle, you would have, would you not, a better average metal, or in other words, a metal containing in one mass all the elements of the cast?

A. You would certainly have in the single cast metal containing all the elements that were in the separate ladles.

X Q. 81. Is it not correct to say that while a furnace cast divided into a series of ladles would give high silicon in one and lower silicon in another, that if the entire cast was run into a large vessel or receiver and there retained for a proper time, the mass in this large vessel, representing the entire furnace cast, would be a better and a safer metal for conversion than the unmixed metal from the separate ladles?

A. Assuming that the proper time mentioned is sufficient
973 to permit a thorough diffusion of the silicon, then I should say that the resultant mass would be better than the separate ladlesful mentioned in the question.

X Q. 82. The law as to the diffusion of metals and the time required for the diffusion, for example, of silicon, is a matter well recognized in the art and understood by metallurgists, is it not?

A. I don't think it is as to the question of time and perfect diffusion. I don't think the law is well developed.

X Q. 83. But that more or less time is necessary is a fact which has been long recognized, is it not?

A. Yes, sir; I am decidedly of opinion that more time is required than is claimed by a good many practitioners of the art.

X Q. 84. If two entire furnace casts should be run together in a mixing vessel they would probably give a better average than a single cast, would they not?

A. If nether were of the desired composition the mixture of both would be nearer an average composition.

X Q. 85. Is it not true that the greater the number of furnace taps that are run together in a vessel the stronger the probability of obtaining a suitable average metal, the furnaces being worked under ordinary conditions?

A. Yes.

X Q. 86. Why or for what reason did you understand that Capt. Jones used ladles between the blast furnaces and the mixer?

A. I understand two reasons for that, one is to be more certain of getting an average mixture by adding successive portions in his mixer than he would obtain if it were all run in at once. The other

is mechanical; it is decidedly a handy way to take the product of a number of furnaces to a common centre for further distribution.

X Q. 87. In fact is it not a fact that ladles were an ordinary and, at the date of the Jones patent, the only thoroughly practical means for conveying the molten metal from the furnaces to a mixer remote therefrom?

974 A. I believe so.

X Q. 88. As a practical man, do you think that if the mixer vessel were placed near the blast furnaces and the same metal that is introduced by ladles were conducted to the mixer by runners, that the process would be a different one, practically, from that of Jones?

A. It would certainly be a different practice. How much it would differ in results I could not answer, because I never heard of it being tried; I don't believe it ever was tried.

X Q. 89. It is in evidence that in the direct practice prior to the Jones mixer it was customary to tap the blast furnaces in succession. Does this accord with your recollection of this practice?

A. I believe that was the Terrenoire practice as published, and either Windsor Richards or Mr. Snelus stated that they worked that way. This is my recollection of it.

X Q. 90. If you should read that an inventor proposed "to place a vessel to receive the molten metal tapped from two or more blast furnaces to get a better average of metal which will be more suitable for making Bessemer steel or metal of uniform quality," would this convey to your mind clearly the idea that the inventor proposed to mix differing blast-furnace metals to get a better average for conversion?

A. I think it would give that impression.

X Q. 91. Would it give you any other impression, or is it in your mind capable of any other interpretation?

A. If an inventor stated that he proposed by mixing metals to get a better average, it would convey to my mind that he meant that and nothing else.

X Q. 92. Have you examined with any care at a recent date the English patent of William Deignton, No. 3672 of 1873, being one of the patents set up by the defendants in this case?

A. I have recently read that patent.

Adjourned to meet June 10th, 1897, at 10.30 a. m.

975 PITTSBURG, *June* 10, 1897.

Met pursuant to adjournment.

Present, as before.

Cross-examination of Mr. METCALF resumed:

X Q. 93. The patentees, Jones and Deighton, both deal with the ordinary Bessemer practice for making steel, do they not?

A. So far as converting the steel, they do.

X Q. 94. Is it not a fact that both patentees, Jones and Deighton, propose to make their Bessemer steel from the same material, that

is to say, from molten iron taken from the blast furnace before it is allowed to solidify?

A. Yes, sir.

X Q. 95. Is it not a fact that the patents of Jones and Deighton both recognize the fact that molten iron coming from the blast furnaces is of variable quality?

A. Yes, sir.

X Q. 96. Is it not a fact that both patents of Jones and Deighton recognize the desirability of equalizing the blast-furnace metal or overcoming its irregularities, in order to secure a more uniform product, that is to say, steel?

A. Yes, sir.

X Q. 97. Is it not true that the patents of Jones and Deighton both propose to effect the equalization of the blast-furnace metal for the converters and to secure thereby a uniform product, by mixing molten blast-furnace metals differing in quality, in a common vessel or mixer?

A. Yes, sir.

X Q. 98. It is in evidence in several places in this case that it was the practice in the direct process to tap the blast furnaces in rotation or succession. Do you read in the Deighton English patent any statement that he proposed to alter this customary order of tapping the furnaces, or that it was necessary, in using his mixer, to depart from the usual method of tapping the furnaces in succession?

976 (The first part of the question is objected to, for the reason that it is believed to be an incorrect statement that it was the practice in the direct process to tap the blast furnaces in rotation or succession.)

(Attention is called to the answers of the witness Gayley, Nos. 249–252, and Julian Kennedy, answers 38 and 39.)

A. The Deighton patent struck me as of such a crude description as not to give any clear idea of how he proposed to manipulate it.

X Q. 99. Do you find in the Deighton patent any language which would forbid him from following the usual practice of tapping his blast furnaces in rotation or succession?

A. There is nothing in the description to show how he works it.

X Q. 100. Do you find, in the specification or drawings of the Deighton patent, anything which renders it impossible for him to tap his blast furnaces in succession in the ordinary manner, and if so, please point it out?

A. No, sir; as I said before, I found no instructions in that patent.

X Q. 101. As a skilled engineer and metallurgist, do you see anything in the drawings of the Deighton patent, as read in connection with the specification, which would prevent him from tapping his blast furnaces in succession as usual?

A. No, sir.

X Q. 102. In running a plant of four blast furnaces to be tapped into a common vessel or mixer, as Deighton proposes to do, would it not be cheaper and easier, by shifting his crews, to tap his fur-

naces in succession, rather than to arrange for tapping them all at one time?

A. I should judge not necessarily. I don't understand that the blast furnace requires a separate crew for tapping furnaces;
977 regular crews around the furnace do that work also. I state this, subject to correction by persons more familiar with the management of blast furnaces than I am.

X Q. 103. Probably I did not make my meaning quite clear. Could not four furnaces be handled more economically as regards labor, if arranged to be tapped in succession, rather than simultaneously?

A. I never handled a blast furnace practically. I do not feel competent to give a satisfactory answer.

X Q. 104. Based on your experience and knowledge, do you see anything in the construction or arrangement of the Deighton apparatus which would prevent him from tapping his blast furnaces in rotation or succession, as usual?

A. I see nothing there that would prevent his trying it.

X Q. 105. Is it your understanding of the Jones method that the mixing vessel may be larger or smaller, and that the successive charges entering the same may be larger or smaller, provided only they bear such relation in size and number that the resulting mixer metal will possess the proper qualities for conversion?

A. That is my impression of the Jones method.

X Q. 106. Is it your understanding that the size of the mixing vessel and the size of the ingoing charges of furnace metal are to be determined in each plant by the judgment of the engineer, based on the conditions of the plant?

A. I should say that that would be the practice. The engineer having informed himself as to the condition of the art up to the time, would probably make such modifications in proportion as in his judgment would best suit his plant.

X Q. 107. Referring again to the Deighton patent, bearing in mind that he was dealing with molten furnace metal, that he had as many as four blast furnaces, and that he proposed to mix the variant metal from these furnaces in a common vessel to obtain, as he says, "a better average of metal which will be more suitable for making Bessemer steel;" do you see any reason, as a prac-
978 tical man, why he should, or why he should not, have tapped his blast furnaces in succession or rotation?

A. If he could work his process at all, I should judge that he would have a better chance to do so by tapping simultaneously.

X Q. 108. Why?

A. Because every time he taps he would meet a serious difficulty, and the fewer number of taps the fewer times he would meet them.

X Q. 109. Is it a more simple or an easier operation to tap and drain four furnaces through a common runner at one time than it would be to tap them successively?

A. If you are going to run them all into a common pool, and that an open one, as Deighton drawings suggest, I should say yes.

X Q. 110. Assume that the Deighton reservoir has a lid or cover, and answer the same question.

A. A lid or cover might help to remove some of the difficulties in the process.

X Q. 111. Do you think it would be better for Jones to conduct the furnace metal contained in a number of ladles into his mixer at one operation, rather than to introduce the same metal in successive portions?

A. No, sir; I do not.

X Q. 112. Have you calculated or considered the capacity of the mixing vessel *m* of the Deighton patent in relation to the furnaces or converters therein shown?

A. No, sir.

X Q. 113. At the Edgar Thomson works about one-sixth of the volume of metal in the mixer is required for their converter charge, is it not?

A. If they take 14 tons out of 80 tons, yes, sir.

X Q. 114. You have spoken of the general recognition of the value of the Jones process. Is it not a fact that it was about five years from the installation of the first plant before it was put into use anywhere else in America?

979 A. I don't know anything about that.

X Q. 115. You know, do you not, that the complainants in this case ran two Bessemer steel plants without the Jones process some nine years after the patent was issued?

A. I do not.

X Q. 116. Do you know anything to the contrary?

A. No, sir.

X Q. 117. You state in answer 29 that you have read various patents and publications set up by the defense in this case. In answer 14 you distinguish the Jones process from any process in which the metal is "simply dumped into a huge vessel in whole taps and drawn out again and the vessel drained and carried off without time being given and care used to produce this averaging-up and this slow changing of the composition of the metal." If you mean by this that either of the patents or publications set up in defense contain any language such as you have used, or any language saying that the metal was drawn out quickly or before it had time to average or mix, you will please read into the record as your answer all the language referred to, giving the page and line where it is to be found.

A. I would not pretend to quote anybody. I probably gave a very emphatic statement of the ideas conveyed to my mind by the Deighton patent, which I regard as exceedingly crude, and possibly some similarly indefinite statements in the miles of literature on this subject that we have had in the past 25 years.

X Q. 118. Bearing in mind that the express purpose of Deighton was to mix the variant blast-furnace metal in a common vessel "to get a better average of metal which will be more suitable for making Bessemer steel;" further, that he says, "y^1, y^2, y^3, y^4 are gates or channels for the molten metal from each furnace, which channels

lead to a receiving vessel *m*, which forms a receptacle for mixing the molten metals from two or more smelting furnaces." And further, that he claims "the system or mode of arranging and working Bessemer converters with a receiver or receptacle *m* for mixing the molten metal from two or more smelting furnaces to get a more uniform quality of metal;"— Is there any warrant for saying that he (Deighton) intended to remove or draw out the metal before it had time to mix or mingle thoroughly?

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A. Yes; he would have to do it, or he would never get it out at all.

X Q. 119. Why?

A. He provides no means for retaining the heat, and no continuing successive charges to maintain the temperature. If his metal were not withdrawn quickly it would set and clog up the whole apparatus, and that is what I think would happen to any one who had the hardihood to try the plan suggested by Deighton.

X Q. 120. That the court may see the basis for your opinion, please read into the record the words and all the words of the Deighton patent which state that he does not draw successive taps or charges into his mixing vessel *m*, if such there are.

(Objected to, because the question is not what Deighton in his patent states he does not do, but what he states in his patent he does do; it is not to be assumed as against a subsequent patent that Deighton did or proposed to do every possible thing which he does not state that he does not do.)

A. I don't believe there are any such.

X Q. 121. How long have you known molten metal to be held in open vessels for conversion on the Bessemer plan?

A. As I explained before, I never handled a large plant. A 10-ton ladle could be held somewhat longer than a small one, say a 3-ton. I think we often held our 3-ton ladle a half an hour, but we didn't like to do it because it lost so much heat.

X Q. 122. Do you not know that it was long the practice in Europe to carry molten metal in open ladle cars a number of miles and retain it in these ladles a number of hours before it reached the converters?

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A. It is on record that they carried iron several miles. I don't remember that it is on record that they held it several hours, and I never saw any statement that any one enjoyed the operation.

X Q. 123. Referring to the Whitney car-wheel plant, which you saw in operation, is it not a fact that metal was there melted in several cupola furnaces, that this metal was drawn from the several furnaces into a large receiving vessel hung on trunnions and provided with means by which it could be tilted, and that from this accumulated mass of metal in a large vessel, relatively small portions were drawn from time to time through the day for use in the foundry?

A. Your words "through the day" spoil your question. They used that plan in the afternoon when they were casting their car wheels. That describes ordinary foundry practice.

X Q. 124. During the time that the Whitney foundry was running, there was a large reservoir or mixing ladle, into which metal was drawn from time to time from three cupola furnaces, and from which relatively small charges were drawn from time to time by tilting the vessel?

A. Yes, sir.

X Q. 125. And at the Whitney works then, they maintained in a large ladle or receiver a mass of molten metal from several cupola furnaces, to which mass molten metal from the several furnaces was added from time to time, and from which mass the metal was removed in relatively small portions from time to time as required?

A. Yes, sir.

X Q. 126. And at the Whitney works, additions were made from time to time to the mingled mass of metal in the vessel, without first emptying or draining it?

A. Yes, sir.

982 X Q. 127. In the casting of car wheels as at the Whitney works, it was necessary, was it not, that the metal drawn from the mass in the large ladle or vessel should be uniform in composition, and also uniform, or practically so, in temperature, to secure the proper chilling?

A. Yes, sir.

X Q. 128. In giving your views as to the uniformity of the cupola metal at the Whitney works, were they based on your general knowledge or on a specific knowledge of the metals used and the working of the cupolas at the Whitney works?

A. They were based on my general knowledge of the foundry business, and on my reading of Mr. Whitney's testimony, in which he describes their operation, which are exactly what I should expect from such experienced and skillful founders.

X Q. 129. Mr. John R. Whitney, one of the proprietors of the Whitney works, referring to their operation, has said in answer 9:

"As the mixture was charged into each cupola, as I have stated, it was made up of irons from various furnaces, some iron having one quality and some another. As it is melted in each cupola, it did not all melt at the same time, and if we had drawn it directly from the cupola into the small ladles from which we poured the wheels, one wheel might have been poured out of very hard iron, another wheel out of very soft iron, and so every shade between. There would have been no uniformity in our work. But by taking it from the three cupolas, all melting the same charges of iron, and collecting them in a molten state, the inequalities of melting were all overcome and a uniform product produced."

Is your knowledge of the Whitney operation such that you feel warranted in denying Mr. Whitney's statement as to the irregularities of the cupola metal, or the fact that they overcame

983 these irregularities by collecting the different charges of molten metal in the one large vessel at his works?

A. Mr. Whitney describes charges of one ton, I think. If, when his cupola began to melt, he had started then to take out one car-wheel weight at a time as fast as melted, he would undoubtedly

have had much more irregularities in his metal than he had in the way in which he worked, but it must be understood distinctly that no good founder, within my knowledge, ever did run a furnace in that way, and it was the efforts to run blast furnaces in that way which caused all the trouble in the direct process, and it was those troubles which Jones overcame by his method.

X Q. 130. Then you agree with Mr. Whitney that he overcame the difficulties which would have attended the taking of single ladles of metal from the cupolas by running the cupola metal into the large ladle, maintaining the mixed or mingled mass therein and taking from this large mass the smaller amounts as required for use?

A. Not necessarily. If he had withdrawn each charge of a ton when it was all melted, and then cast it into wheels at the right temperature, he would have had practically as good results as he did with his big ladle.

X Q. 131. Do you deny either of the statements made by Mr. Whitney in his answer 9, quoted to you above?

A. No, sir, I have not denied anything.

X Q. 132. Have you any reason to believe that either of the statements contained in Mr. Whitney's answer 9 are untrue?

A. No, sir.

X Q. 133. Touching your opinion that Deighton would have to remove metal from his mixer "quickly;" have you had any practical experience in holding molten metal in a vessel large enough to contain four blast-furnace taps?

A. No, sir, I have not.

X Q. 134. Deighton proposes a vessel into which he may
984 tap the entire cast from two or even four blast furnaces. Can you express any definite opinion based on experience as to the length of time for which he could retain the molten metal in such a vessel and in condition for conversion, assuming the vessel to be proportioned as shown in his patent drawings?

A. I suppose he could hold it about a half an hour.

X Q. 135. It is your idea, then, that a mass of say 50 tons of molten blast-furnace metal could only be retained about a half an hour in an open vessel in condition for conversion?

A. Yes, sir, talking of the whole mass.

X Q. 136. But you have never had any actual experience with such a mass?

A. No, sir. I have had enough experience to know how it would act, though.

X Q. 137. Up to the time of the Jones mixer, what was the most common means employed to prevent rapid cooling of molten metal when held in mass?

A. By sprinkling coke dust or charcoal dust, or even putting small sticks of wood on the surface to make a slack combustion which would partly compensate for radiation, and also a cover which would tend to prevent the same.

X Q. 138. This method of preventing the loss of heat from molten

metal was common and well understood before the Jones patent, was it not?

A. Yes, it was common practice in foundry work.

X Q. 139. In your direct testimony, referring to Mr. Durfee's paper, you say that it "was his intention when he received in the furnace iron which was not of proper composition for blowing, to remedy it by additions of such other metal of varying composition, and melting it in with his charge as would bring the whole batch up to the desired condition." Did you notice that Mr. Durfee also proposed, instead of melting in solid iron, to secure the desired quality by adding to the molten blast furnace iron molten iron from another source?

985 A. That statement may be there. I don't remember distinctly now of noticing it.

X Q. 140. When you answered Q. 26, did you have in mind this statement of Durfee as to combining or mixing molten metal from two sources?

A. I think so. I think probably I noticed in reading it over that he made such statement; whether he did or did not would not affect my answer.

X Q. 141. Referring to the Durfee patent and publication—he was dealing with the manufacture of Bessemer steel and the use of blast-furnace metal as melted in the blast furnace for the purpose, was he not?

A. Certainly, in which he proposed to use an intermediate open-hearth furnace for holding his iron.

X Q. 142. And Durfee recognizes the necessity of modifying or correcting the blast-furnace metal for "producing uniformity of quality in iron for conversion by the Bessemer process," does he not?

A. Yes. That is a matter of the commonest knowledge all over the metallurgical world; everybody recognizes it.

X Q. 143. And Durfee recognizes, does he not, that the uniform metal for conversion is to be obtained by mixing bodies of molten — which differ from each other?

A. Yes. That again was common knowledge; every one knew of it that knew anything about the business.

X Q. 144. And it is also true that Durfee proposed to mix the variant molten metals to secure the desired metal for conversion, by introducing into a "mixing furnace" a molten metal from the smelting furnace and from the other furnaces or cupolas in which the selected metal is melted?

A. I believe that is correct.

X Q. 145. Gas furnaces, such as a Siemens regenerative furnace can be operated at will, with or without a reducing flame, can they not?

A. Yes. By a man sufficiently skilled to handle them properly.

986 X Q. 146. Are you familiar with the mixing vessels or reservoirs used at the Edgar Thomson and the Cambria works?

A. I never saw the Cambria mixer. I have seen the Edgar Thomson.

X Q. 147. Do you know that a gas flame is used in connection with the Cambria vessel?

(Objected to as not cross-examination.)

A. I never saw the Cambria flame.

X Q. 148. Then you have no knowledge of the use of the gas-heating flame in either the Edgar Thomson or the Cambria mixer, or of the effect of such flame on the molten metal?

A. I can't have in regard to the Cambria; I never saw it. Of course, I read what is in the testimony in regard to it. I don't remember now whether Jones made any reference to the gas flame or not when he showed me the plant; it is many years ago.

X Q. 149. How long has it been since you saw the Edgar Thomson mixer in operation?

A. Mr. Jones showed it to me some time in the eighties.

X Q. 150. Referring to your Manual on Steel, it is not directed to and does not bear at any length on the Bessemer practice, does it?

A. No, sir; it does not treat of the manufacture of steel in any way extensively; it is a mere brief description of the manufacture, and then the work is devoted to the properties and physics of steel.

X Q. 151. Referring to the casting of the guns at the Fort Pitt foundry, the molten metal from the different furnaces was delivered into, and was in a molten condition in the mold until the completion of the pouring operation, was it not?

A. I think so. I don't think any part of it had time to set before the completion of the casting.

987 X Q. 152. In your answer 24 you have referred to the language of Mr. Holley in his 1877 report respecting the condition of steel manufacture in Europe. Is it not a fact that Mr. Holley says also in that report, in dealing with molten metals in fact this mixing of irregular irons on a very large scale, thus avoiding the expensive niceties of ore selection and the necessity of many furnaces, is the theoretical key to the situation?

A. I believe that is correct. I believe that Holley saw the difficulty more clearly than anybody in the world, probably he may have furnished the key, but he didn't find the lock—he didn't furnish the solution.

X Q. 153. And the Holley 1877 report further says, does it not, in this connection, "but the mixing problem was not such a difficult one. A small amount of flame spread over a large surface of metal should certainly keep it hot for a long time, seeing that the metal will keep hot in a ladle exposed to the air for an hour or more. And should there be any trouble about stopping the tap-hole in a large pouring furnace, it would not be very difficult or expensive matter (considering the Pernot revolving-hearth experience), to tip the whole hearth enough to pour a charge"?

A. I believe that quotation is correct. Holley with his keen mind and vivid imagination evidently at that time was thinking of the application of an open-hearth furnace, such as suggested by

Durfee and modified by his idea of the Pernot furnace. It was a mere suggestion, and to carry it out would, I am satisfied from a large experience, have cost as much as, if not more, than the cupola practice.

(All after the word "correct" is objected to as voluntary and argumentative.)

X Q. 154. In your last answer you do not refer, do you, to any experience on your part in mixing and holding molten blast-furnace metal in an open-hearth furnace for use in the Bessemer practice?

A. No, sir.

988 X Q. 155. Mr. Holley was one of the greatest authorities on the Bessemer practice, was he not, and generally so recognized?

A. Yes, sir; he was so recognized all the world over.

X Q. 156. In your answer 14, in defining the Jones process, what do you mean by "successive portions"?

A. I mean just as Mr. Jones explained to me that the metal as taken from the furnace was put into ladles and those ladles were successively poured into his mixer, at such intervals of time as he found expedient.

X Q. 157. In practice the ladles are emptied into the mixer as rapidly as possible, if there is room for the admission of the metal, are they not?

A. I don't know that, but I should suppose they would be.

X Q. 158. Do you understand that the use of ladles between the blast furnaces and the mixing vessel were vital or necessary to the Jones process?

A. I think I answered that before. They are not vital, but extremely handy and convenient.

X Q. 159. What features of convenience to the workmen or to the working of the plant are there in the Jones method as compared with the ordinary direct process?

A. I don't know of any special difference in convenience to the workmen where they use ladles in the ordinary process.

X Q. 152. Is it not a convenience to have a large reservoir or storage of metal ready to be drawn upon for the converters of any kind?

A. I should judge that it would be so.

X Q. 153. Is it not an advantage to have between the blast furnaces and the converters a large reservoir or storage place for the molten metal, so that the furnaces may be tapped instantly whenever they happen to be ready, whether the converters are ready to receive the metal or not?

989 A. It seems to me that those experienced in the art have testified that that is so; I have had no experience in the management of blast furnaces myself.

X Q. 154. Does not your experience as an engineer and metallurgist indicate to you that it is an advantage to have between the blast furnaces and the converters a storage vessel in the nature of

an equalizer, so that the furnaces may be tapped whenever they happen to be ready and without regard to the converters being ready at the time to receive the metal?

A. Yes. As a general proposition that strikes me as desirable.

X Q. 155. And there would also be an advantage in this intermediate storage vessel in that it could furnish metal to the converters when required, although the blast furnaces might not be ready to deliver it when required?

A. Yes, sir.

X Q. 156. Referring to the 20-inch gun cast at the Fort Pitt foundry, and to the other gun castings made there, did you intend to be understood that there was no mixing of the metal from the three furnaces in passing into and through the pool between the furnaces and the gun mold or molds?

A. I didn't intend to say that there was no mixing, because you can't run two streams of metal together without some mixing; but I did say that the claim of the running of the metal in that way was done with any view to mixing whatever is simply absurd and was not a fact.

X Q. 157. What did you mean in your testimony in referring to the castings of the solid gun and the hollow guns at the same time in saying that they were cast in the manner described, so that no one could claim that either gun was "petted"?

A. I said that because that was the fact. As I explained there was a very bitter contest or rather serious differences of opinion among gun experts as to the probable value of Rodman's in-
990 vention, and this particular mode of casting was arranged so that it was impossible for either side to say that there was any favoritism shown to either gun. That was the only reason for casting them simultaneously.

X Q. 158. How did you prevent either gun from being "petted"?

A. By running the metal from the furnaces first into a little catch-pool which would have been used anyhow where two furnaces are used at the same time, and from there running it out in a single runner some distance; when that stream was divided into two, one of which was carried to each mold, a very simple device to make it impossible for any one interested by manipulating the furnaces to insure that a different iron would go into one gun from that in the other.

X Q. 159. And the iron from the two or three furnaces was mixed in passing through this pool and in passing along the runner to the point where the runner branched and led to the two molds?

A. There was some mixing of course as long as the iron was running from the two furnaces simultaneously; while the first iron was only coming from the first furnace; and while the latter part was coming from the second furnace, there was certainly no mixing.

X Q. 160. Did you intend to include in your answers as to the guns at Fort Pitt the publications in evidence, which referred to the metal discharged from the furnaces "by separate streams into a common reservoir at the same time" and again "was discharged from all the furnaces at the same time into a common reservoir,"

these quotations being made from the report on the "Manufacture and proof of 8-inch and 10-inch columbiads, cast at Fort Pitt iron works, by Messrs. Knap & Co., 1851," as found in the "Reports of experiments on the strength and other properties of metals for cannon"?

A. One of these reports says that the metal was then discharged by separate streams into a common reservoir, and the other says at the same time. It don't matter particularly whether they
991 were discharged at the same time or successively; the pool was not used as a mixer during my time, nor I don't so read it there. Rodman's report speaks of consecutive tapping.

Adjourned to meet June 11th, 1897, at 10.30 a. m.

PITTSBURG, *June* 11, 1897.

Met pursuant to adjournment.
Present, as before.

Cross-examination of Mr. METCALF resumed:

X Q. 161. Do the different kinds of pig metal melt at the same temperature, either in the cupola furnace, or in the blast furnace?

A. No, sir.

X Q. 162. Which melts at the higher temperature, the cold-short or the red-short pig metal?

A. I don't think cold-short or red-short has anything to do with it. It is a question of the quantities of silicon and carbon present.

X Q. 163. Please explain how the silicon and carbon affects the temperature at which the different pig metals melt?

A. An iron high in silicon and carbon melts at a lower temperature than iron lower in silicon and carbon. This difference continues until you reach wrought iron, which requires the highest temperature to melt.

X Q. 164. Then steel scrap will melt at a higher temperature than pig metal. Is this correct?

A. Yes, sir.

X Q. 165. Are all pig metals desiliconized to the same extent in passing through and remelted in cupola furnaces?

A. I can't answer that question. When I had my large experience in the use of cupolas, we had no chemical laboratory connected with our works.

X Q. 166. During what period was it that you had your large experience with the use of cupolas?

992 A. From 1858 to 1868. When I used a cupola later, in the steel business, it was for a purpose where we didn't care anything about silicon and paid no attention to it.

X Q. 167. Are all pig metals desiliconized to the same extent in being remelted in an air furnace?

A. The desiliconizing depends entirely upon the character of the flame to which the iron is subjected. Iron can be remelted with

practically no change in the quantity of silicon, and it can be almost desiliconized in the operation of melting.

X Q. 168. You have stated what causes the desiliconizing of the pig metal. I want to know in addition whether all pig metals are desiliconized to the same extent under like circumstances in the air furnace?

A. They are all certainly effected in the same way, but whether exactly in the same proportions during the same time, I could not say; there might be a difference in the rate at which the silicon would run out.

X Q. 169. In the use of a cupola furnace, does the heat of the furnace have any relation to the rapidity with which different pig metals melt in the furnace?

A. I think it has, decidedly.

X Q. 170. Please explain this so that it may be understood by the court.

A. I think we may safely lay down as a rule that all melting operations are accelerated by every added increment of heat. This action will effect all metals alike, but of course the effect will be different in degree or rate for irons of different composition.

X Q. 171. Under the general rule stated in your last answer, which pig metal would melt the more rapidly, that of high or of low silicon, or that of high or of low carbon?

A. The melting of all would be accelerated by any additions of heat above the mere melting temperature.

X Q. 172. And if these different kinds of pig metal were present in a cupola, and the melting temperature thereof was sufficient to melt some and not the others, that metal would melt and come down before the other, would it not?

993

A. Certainly it would.

X Q. 173. Under the circumstances of the practice at the Fulton foundry, referred to in question and answer 22, where both air-furnace metal and the cupola metal run into the same ladle, would there not be a mixture in evening up the composition of the two metals, where the metal stood for a sufficient time in the ladle?

A. Yes, sir. You can't pour two metals together without making a mixture.

X Q. 174. And this rule applies to what you have termed foundry practice, where the metal from the cupola is run into a ladle either continuously or by successive tappings, and small portions of that metal are withdrawn from this ladle from time to time as needed, some metal always remaining in the ladle. Is that also true?

(Objected to for the reason that it is merely a hypothetical question.)

A. Yes, sir.

X Q. 175. Was this rule recognized during the time you were directly connected with foundry practice, that is from 1858 to 1868?

A. It is a simple fundamental law of nature; I suppose it was always known every since man began to observe nature's laws.

X Q. 176. In answer 28 you referred to the use of a gas pipe in the Jones mixer "to warm it up a little." Please describe the way in which the heat would be applied to the metal in the mixer in warming it up.

A. It would be radiated from the flame to the surface of the metal.

X Q. 177. Would the heat of the flame be radiated in any way by the roof of the mixer?

A. Yes. I suppose all solid bodies will radiate some heat.

994 X Q. 178. Then the metal in the mixer would be warmed up by the flame passing over the metal and its direct radiation upon the metal or radiation through the roof, is this correct?

A. Yes, sir; that is about the way it would act.

Redirect examination by complainant's counsel:

R. D. Q. 179. State whether you have seen and read the newspaper report offered in evidence by the defendant, in regard to the casting of the Rodman gun at the Fort Pitt foundry, and whether that statement and report are correct?

(Objected to as not proper redirect examination.)

A. I read part of a report this morning taken from the Pittsburgh Daily Commercial dated Feb. 12, 1864. That report is not correct; it got the Pennsylvania railroad into very serious trouble and expense at the time.

R. D. Q. 180. State in what respects it is incorrect.

(Objection continued to this line of examination.)

A. It is a fair newspaper reporter's account of what was a very interesting event at that time, containing a good general description and numbers of technical errors. For instance, where he says that the furnaces were tapped simultaneously, that is an error. Where he said that there was a heavy preponderance in the gun, that was an error that cost the car-builders a great deal of money.

R. D. Q. 181. Have you any experience in the use of a gas furnace for melting pig iron and for holding it in a molten condition?

A. Yes, I have had a large experience; first in melting a great deal of iron for use in rotating mechanical puddling furnaces; and, second, for use in the Bessemer process, instead of melting in cupolas.

R. D. Q. 182. Please to explain in what way you used it in revolving mechanical puddling furnaces?

995 A. We had a 15-ton furnace in which we melted and had ready every morning about 10 to 12 tons of iron. We worked by tapping out charges of about 1,800 pounds and using them successively in the rotators, which are the mechanical puddling furnaces spoken of in the last answer. As these charges were withdrawn, more iron was added and melted in the furnace, until toward the close of the day we had melted all we could use, generally about 20 tons, involving about 15 taps of the furnace.

R. D. Q. 183. State whether or not you used a similar furnace in your Bessemer department, and in what way?

A. We used a similar furnace and almost in precisely the same way, except that the withdrawals were about 3 tons and the manipulation was somewhat different.

R. D. Q. 184. State whether or not you experienced any special difficulties in this practice, and if so, state what they were.

A. There were two special difficulties in the puddling department, and an additional one in the Bessemer. The first trouble was with the tapping hole. Owing to the frequent tapping it was extremely difficult to keep this in order, and in a number of cases the whole charge broke out, cutting away the plates and beams of the furnace, spilling the iron all over the floor, and causing very serious delay and expense. This required us to be on the watch constantly and to have two men at the tapping hole where we had supposed that one would be sufficient. This break-out is always a matter of dread in handling a furnace of that kind, and the risks are increased enormously by frequent tapping. The second trouble in the puddling department was the formation on the bottom of the furnace of what puddlers call "nature iron." This fuses with great difficulty, and if every particle was not removed every day this iron would grow until it did actually, in some cases, so fill up the furnace that the furnace would not hold a charge sufficient to
996 work with. Then we had to shut the furnace down, tear out the sides, remove the "bear" with hydraulic jacks, and then rebuild the furnace. Several such bears are buried in our cinder pile, which weigh from 15 to 20 tons apiece.

In the Bessemer department, the first difficulty was just as conspicuous and troublesome as in the puddling department. The second was not quite so much so, but we had a third troublesome difficulty to overcome, in the fact that we were liable to burn out the silicon and carbon to such an extent that the metal would not blow properly. This trouble caused us a number of serious skullings up before we got our men trained to handle the furnace so as not to desiliconize and decarbonize the iron. We found in both departments that we required men of about as much skill as are required in handling an open-hearth steel plant.

R. D. Q. 185. In your examination-in-chief, in speaking of what has been called the Whitney process, you stated that it was simply an old foundry practice brought up by engineering care and skill, and that it was simply a slight advance in the art of founding; and in your cross-examination you stated that you had no reason to believe that either of the statements contained in Mr. Whitney's answer 9 are untrue; please to state whether you meant by this that you approved of and believed in the conclusions which he stated in his testimony.

(Defendant's counsel inquires what is meant by "the conclusions which he stated in his testimony," as the question is indefinite as to this.)

(Counsel for complainant shows to the witness the answer No. 9

in Mr. Whitney's testimony referred to in the foregoing question, as to the correctness of which he is interrogated in the present question.)

A. Decidedly not. Mr. Whitney had already described the exact and minute care with which they selected the ton charges that went into their furnace, even down to so small an amount as 50 pounds. This is good foundry practice, and if the charges of a ton at
997 a time had been withdrawn from the furnace when each and every charge was wholly melted and then cast into wheels, Mr. Whitney would have met with no serious difficulty. Having made his preliminary charges with the great care, his answer attaches undue importance to the effect of the ladle, and if he had not so made his charges for his cupola he would, in my judgment, have been a very careless founder or ignorant of his business.

R. D. Q. 186. What is the maximum quantity of metal that you have known to be melted in a reverberatory furnace in the course of a day?

A. In a reverberatory, 40 tons in the big gun furnace used at Fort Pitt during the war. In a 15-ton regenerator furnace, not more than 30 tons, and that kept us in misery all day.

R. D. Q. 187. About what quantity of metal is passed through the Jones mixer at the complainant's works in the course of a day?

A. My recollection is that when I visited Capt. Jones he was making from 600 to 800 tons of rails in 24 hours; that would make about 300 to 400 tons of metal going through the mixer in one turn.

Recross-examination by defendant's counsel:

R. X Q. 188. Your plant in which you used reverberatory furnace was a very small output with small converter capacity, compared with the Edgar Thomson, was it not?

A. I never used a reverberatory in connection with a converter.

R. X Q. 189. Then you never used a reverberatory furnace in the Bessemer practice?

A. No, sir.

R. X Q. 190. And when you used a reverberatory furnace, it was worked at high temperature and for the express purpose of melting solid iron introduced thereto, was it not?

998 A. Used for melting iron for use in the foundry.

R. X Q. 191. Did you ever have occasion in practice to try the introduction of molten metal to or the mixture of previously melted metals in a reverberatory furnace?

A. No, sir.

R. X Q. 192. In a reverberatory gas furnace, it is possible to use a reducing or a non-reducing flame at will, is it not?

A. I never used a reverberatory gas furnace and I could not be induced to do it.

R. X Q. 193. Do you know within what limits it is possible to control the temperatures in reverberatory gas furnaces?

A. No, I never used one.

R. X Q. 194. What kind of reverberatory furnaces do you refer to in your redirect testimony?

A. An ordinary reverberatory melting furnace, what any engineer would understand by the term,—a coal-burning reverberatory.

R. X Q. 195. When was it that you used the gas furnace for melting pig iron and for holding it in a molten condition for use in rotating mechanical puddling furnaces?

A. I used that for 10 or 12 years, from about 1880 or 1881 to 1892 or 1893, at the Crescent steel works, Pittsburg.

R. X Q. 196. Had this furnace a tilting or rotating hearth?

A. No, sir,

R. X Q. 197. But you had there during that time these puddling furnaces that had rotating hearths?

A. We had revolving puddling furnaces, which were a modification of the old well-known Danks furnaces.

R. X Q. 198. The general type of such Danks furnaces is shown in the Danks patent No. 96206, dated Oct. 26, 1869, a copy of which I hand you, is it not?

A. Yes, sir.

999 R. X Q. 199. How did you carry the molten metal from your melting furnace to the rotary puddler, and in what way did you introduce it into the rotary puddler?

A. We tapped the iron out into a ladle, lifted that with a hydraulic crane, and poured it into the rotators by a spout inserted in the end of the rotators temporarily for that purpose.

R. X Q. 200. In using that melting furnace, you had to use different temperatures, that is a melting temperature to melt down the pig metal, and after it was melted a temperature for holding the metal in a molten state until it was withdrawn from the furnace, is that correct?

A. In the puddling, we practically kept that furnace almost up to steel-melting heat, because it was a great advantage to us to burn out the silicon in the melters to a considerable degree. In the Bessemer operation, we simply maintained as high a temperature as we could consistent with the keeping up a neutral or non-oxidizing flame.

R. X Q. 201. When you used your melting furnace to supply the converters at the Crescent steel works, how much metal did you convert there in a day?

A. We didn't want more than 20 to 25 tons per day, and we didn't convert any more than that as a rule.

R. X Q. 202. How many hours a day would you run, and how many heats would you make?

A. 9 or 10 hours. An average of 20 tons would make an average of 7 heats, that is, 3 tons to a heat.

R. X Q. 203. In A. 187, you refer to Capt. Jones' statement of 600 or 800 tons of rails in 24 hours, and say that would make 300 or 400 tons of metal going through the mixer at one turn. Do you mean by "turn" a full day's work, or do you mean that the amount of metal going through the two mixers that they had there in one turn?

A. As I said I spoke from recollection. I was assuming that they were running what we call "double turn," that would be
1000 two shifts or turns in 24 hours, which would give half of the whole consumption to each turn, and that would give to each of as many mixers as they may have had its aliquot portion of the whole.

R. X Q. 204. Do you know of your own personal knowledge that Mr. Whitney did follow such practice in his foundry as melting down in a cupola charges of a ton at a time and withdrawing that from the furnace, as suggested in your answer 185?

A. Successive charges of a ton. Yes, that is what I understand from his own testimony.

R. X Q. 205. Please look over Mr. Whitney's testimony, and point out any place where he says that he withdrew from the cupolas successive charges of a ton at a time?

A. Mr. Whitney testifies, pages 159, 3d line, "then that mixture was weighed in drafts of about 2,000 pounds each, each draft consisting of its proper proportion of these several different irons, as I have named, 100 pounds of one, 200 pounds of another, etc.; then those drafts were charged every cupola upon a bed of coal between each draft of iron, until the cupola was full, when the blast was put on as this iron melted."

R. X Q. 206. What does Mr. Whitney say about withdrawing the metal from the cupola?

A. He says "a spout leading from each cupola conducted it into the large ladle which stood in front of them."

Redirect examination:

R. D. Q. 207. Will you state whether your experience with the furnaces described by you in answers to Qs. 181–184, showed the same to be satisfactory or desirable?

A. They were satisfactory in so far as we could see no better way to do the work. The continuous holding of iron in a furnace from morning to night was extremely difficult, hazardous and expensive, and I look on it now as a horrid nightmare.

WILLIAM METCALF.

1000 *1 The Carnegie Steel Company, Limited, accounting department.

Statement Showing Percentage of Second-quality Rails Produced at the Edgar Thomson Steel Works, January, 1895, to December, 1896, Inclusive.

Filed by James Gayley in answer to R. X Q. 400.

	1895.	1896.
January	4.93	4.18
February	4.92	5.56
March	3.28	6.24
April	3.91	6.68
May	6.22	6.59
June	4.85	5.86
July	6.06	6.24
August	7.96	5.69
September	4.42	2.99
October	4.58	2.89
November	4.76	4.30
December	6.87	
Average for year	5.26	5.63

The inspection during the past few years has been very rigid.

JAMES GAYLEY.

PITTSBURG, *Sept.* 17, 1897.

Met pursuant to notice.

Present: Bakewell & Bakewell, for complainant; Mr. James I. Kay, for defendant.

(Defendant's counsel objected to the following deposition for reasons appearing in the manuscript record.)

John E. Fry Recalled.

JOHN E. FRY, a witness called for complainant in rebuttal, being duly sworn, testifies as follows in answer to questions by complainant's counsel:

Q. 1. Please state your name, age, residence, and occupation?

A. John E. Fry; age, 59 years; chief occupation, practical steel-maker; residence, Philadelphia, Pa.

1000 *2

Q. 2. Please state whether or not you have recently examined the cupola furnaces in the foundry of Whitney & Sons, Callowhill St., Philadelphia, and the purpose of this examination?

A. I have examined the cupolas referred to quite recently, the purpose being to ascertain such dimensions as would indicate their melting capacity for iron, and the holding capacity of their hearths.

Q. 3. What did you find from your examination?

A. I found three cupolas of similar construction and size that

had been used to melt metal for making chilled cast-iron car wheels. They had been out of use for over a year, the works being idle for that length of time. They are what is known in foundry parlance as a cylindrical 48-inch cupola. They have each a melting capacity of about 6 gross tons per hour, using the local fuel, anthracite coal. Their hearth capacity would be up to 2 tons of liquid iron; that is to say, two-ton taps could be made regular.

Q. 4. I hand you a sketch and ask you to state, if you know, by whom it was made?

A. I made this sketch on July 23d, last, as stated under my signature under the title.

Q. 5. State by whom the figures and writing on said sketch were made, if you know, and when?

A. The figures and writing were made by me at the time stated.

Q. 6. You have stated that their hearth capacity would be up to two tons, referring to two cupolas; do you mean their individual capacity or their joint capacity?

A. I refer to the capacity of each in their individual capacity.

Q. 7. I ask you to state as a practical foundryman whether there were any indications of any change in the dimensions of capacity of these cupolas within recent years?

1000 *3 A. It is quite evident that this melting plant has not been changed for a number of years; even the refractory linings of the cupolas do not seem to have been renewed for several years, certainly three or four years, as indicated by the wear and tear of them. The general construction has every appearance of being 10 to 20 years old.

(Counsel for complainant offers in evidence the drawing referred to by the witness and is marked "Complainant's Exhibit Fry Drawing Crucibles of Whitney Cupolas.")

Q. 8. I hand you two photographs and ask you to state whether you recognize the cupola furnaces shown therein.

A. These two photographs illustrate the cupolas in consideration.

(The witness refers to photographs "Complainant's Exhibit Photograph Whitney Cupolas," heretofore offered in evidence in this case.)

Q. 9. You have stated that the figures and writing in "Complainant's Exhibit Fry Drawing Crucibles of Whitney Cupolas" were made by you; please state whether these dimensions and indications of the parts, as given in the sketch, are correct.

A. So far as they refer to the construction they are practically correct. They could not be mathematically correct owing to the irregularity of the materials that were measured. The cupolas, at the time the sketch was made, were in the same condition they were left when melting operations ceased over a year ago; that is to say, the bottom doors were dropped and the cupola was not in a state of repair. It was necessary for me to make a sketch showing the doors raised in the position they would be in repairing the cupolas, and

to add to my sketch such a sand bottom as to depth as would be put in to prepare the cupola for proper melting operations, this to ascertain the holding capacity of the crucible of the
1000 *4 cupolas. Therefore, the figures indicating the thickness of the sand bottom are assumed and taken to represent a bottom of ample thickness.

Mr. Kay, defendant's counsel, here renews his objection to this deposition as being taken after the complainant's case in rebuttal was closed, and proceeds to cross-examination *de ben- esse.*

Cross-examination:

X Q. 10. What was the date of your visit to the foundry of A. Whitney & Sons, Callowhill St., Philadelphia, referred to in your deposition?

A. I visited the foundry in consideration on the 7th of July and on the 23d of July, 1897.

X Q. 11. When did you visit those works and examine the receiving ladle placed in front of the cupolas, as testified to in your former depositions?

(Objected to as not proper cross-examination.)

A. I do not recall the date when I visited the works for examination of this ladle, but some time in the spring of this year I was in the foundry and made a general examination of the melting plant and of the distributing ladle connected with it.

(In view of the answers 10 and 11, defendant's counsel objects to this entire deposition as irrelevant and immaterial, for the reason that it refers only to a time long after the use of the cupola and ladle referred to in defendant's testimony and long after the grant of the patent in suit, and proceeds with his cross examination *de ben- esse.*)

X Q. 12. Do you personally know that the cupolas you saw at the Whitney works "had been used to melt metal for making chilled cast-iron car wheels; they had been out of use for over a year, the works being idle for that length of time," as stated in your answer 3?

A. Yes.

X Q. 13. How do you know it?

1000 *5 A. I know that those cupolas were used for the special business of making chilled cast-iron car wheels, from having seen them in operation many years ago.

X Q. 14. How do you positively know that they are the same cupolas that you saw many years ago?

A. From the general appearance they present and its effect upon a practical man.

X Q. 15. For all you know, the cupolas which you say you saw many years ago may have been torn down and others built in their place; is not this correct?

A. No; not absolutely correct. It is scarcely possible that an

engineer of the last 25 years would employ the material in construction or put it in the shape the material is, especially in the platforms. The type is too ancient to suppose that it was constructed within 25 years.

X Q. 16. Were you present at those works at any time between the visit made you say many years ago, and the visit you made last spring?

A. I visited those works after the war and before 1871. Again, in 1886 or 1887. Not since this latter date until the spring of this year. I refer of course to the interior of the works, as I have seen them in operation from the exterior often.

X Q. 17. How do you get at the height and capacity of these cupolas that you say would be two tons each?

A. By measuring its cubical capacity, and comparing that with the iron and fuel it would contain when in operation.

X Q. 18. Please state in detail how you measure its cubical capacity and reach the conclusion that it will hold two tons of liquid iron.

A. This hearth is cylindrical. A simple arithmetical calculation will find its area from its diameter. The area multiplied by the depth gives the cubical capacity, expressed in any dimension of measurement used. Referring to the contents, the weight of a cubic foot of liquid cast iron is well known, and also that of a cubic foot of fuel. With these factors and a practical knowledge of the proportion of iron and fuel in the hearth of a cupola in operation, a definite conclusion is reached as to the capacity of that hearth for holding liquid iron.

1000 *6

X Q. 19. You have given the rule to get at this matter. Now please calculate the same and state it upon the record so that the court may understand how you fix the capacity of a cupola hearth as two tons of molten iron.

A. I have given two tons as an amount that could be readily accumulated in the hearth in question, but that does not represent its total capacity. It is given as a quantity that could be tapped again and again in foundry practice. The hearth is 48 inches in diameter. The area of 1 inch in height of this diameter would be about 1,810 square inches. The working height of the hearth, as shown in the sketch in evidence, is taken at an average of 16 inches. It might be a little more or less, according to the way the cupola-man put in the bottom or fixed the size of his tuyere holes. These dimensions would give about 28,960 cubic inches. The weight of a cubic inch of cast iron is $\frac{263}{1000}$ of a pound. This capacity would contain about 7,616 pounds of cold cast iron, or about 7,540 pounds of liquid iron, and this would be the total holding capacity of this hearth at 16 inches in depth, if only liquid iron were contained therein. But a hearth of a cupola in operation contains some fuel, because it is necessary that there should be a bed of incandescent fuel extending up to a point a couple of feet above the blast tuyeres, so that the iron will be melted above the tuyeres and not pass in a solid state below them to chill the iron there already melted. When the hearth contains no liquid iron, the fuel mass extends to the bot-

tom of the cupola. As melting proceeds, the liquid iron accumulates at the bottom, at first filling the spaces between the fuel lumps there, and after a considerable quantity is melted the superior gravity of the liquid iron over that of the fuel lumps buoys the latter up,
1000 *7 leaving a practically clear space, as regards fuel, in the bottom of the hearth. This floating up of the light fuel mass below the tuyeres is a phenomena familiar to all practical cupola men. The difference in gravity referred to would be in the ratio of about 9 for iron and 1 for fuel lumps, so that the floating power of the iron is quite considerable. With this hearth, full of liquid iron to the tuyeres, it is impossible to fix the exact quantity of fuel which is submerged in the liquid iron, as this would vary, not only due to the character of the fuel, but to the melting operations also. From long practice in the tapping of cupolas, I am safe in stating that with the most refractory fuel there would be not more than 40 per cent. of the hearth space occupied by fuel, leaving 60 per cent. to contain liquid iron. With this reasonable assumption, the content of the hearth of the Whitney cupola as shown in the sketch, would be about 4,400 pounds.

I have said that experience indicates the floating up of the fuel as the hearth fills with liquid iron. If a tapping bar were to be inserted when the cupola was drained of liquid iron, the cupola tapper would find fuel lumps in the way of his bar as he tried to thrust it in; but when there is a quantity of liquid iron in the cupola, he can thrust in his bar freely and move it around, feeling that there is no fuel in the way. Again, in looking through the sight-holes of the tuyeres, when the liquid iron is rising in the hearth, the floating up of the fuel is plainly to be seen, the fuel in the hearth and for some distance above the tuyeres being as "loose as ashes," to use a familiar expression. I am safe when I fix the maxium of fuel lumps in the hearth at a volume of 40 per cent. of its capacity, and a minimum of 4,400 pounds of iron safely held at the same time.

X Q. 20. In making the above calculations in fixing 16 inches from the depth of the metal, you have calculated the depth from the base of the tuyere opening down to the surface of the sand bottom, have you not?

1000 *8 A. Yes, sir. The practical depth of the hearth of this cupola would be 16 inches, a trifle more or less as modified by the cupola tender.

X Q. 21. Does your answer 3 refer to ton tappings of 2,000 pounds or 2,240 pounds?

A. A foundry ton is generally 2,000 pounds. My previous answer relating to weight is given in pounds, closely approximating two gross tons. I refer in answer 3 to gross tons of 2,240 pounds each.

X Q. 22. If the metal were allowed to rise above the bases of the tuyere opening, what would be the result?

A. In such cases, the blast would be obstructed in its entrance, and if the metal were allowed to remain there any length of time it would chill in the tuyere opening.

X Q. 23. What effect would this have upon the action of the cupola?

A. A partial stoppage of the tuyere with metal would reduce the rate of melting proportionally as the quantity of blast was reduced. If the tuyeres were chilled up entirely, it would stop melting operations.

X Q. 24. Would it affect the quality of the metal produced in any way?

A. It would have no effect upon the physical or chemical quality of the metal. It would only retard or stop the operation, as stated.

X Q. 25. It would lower the heat of the cupola, I suppose, in proportion as it reduced the supply of oxygen for combustion with the carbon of the fuel?

A. In the case of a diminished blast from the cause stated, the combustion of the fuel would be as intense but not as rapid. The cupola can be run at a very slow rate, and still melt the iron satisfactorily hot.

X Q. 26. Would not such reduction of the blast actually lower the heat within the cupola?

A. Melting would go on slower as the quantity of blast
1000 *9 was reduced, but the cupola would not necessarily be reduced in temperature, if this obstruction of the blast were within reasonable limits. It is not at all unusual to check the quantity of blast delivered within a given time for the purpose of melting slower to suit some other features of the work. It does not follow that less than the maximum quantity of blast which can be supplied through the tuyeres of a cupola would result in melting the iron at a lessened temperature. It would only retard the rate of melting, as said before.

X Q. 27. Considering the distance from the bases of the tuyere opening of the cupola bottom to be 16 inches, and that this difficulty of obstructing the blast might arise if the metal was permitted to enter the tuyere openings, how high would it be safe in the practical running of the cupola to let the metal rise in the hearth?

A. It would be perfectly safe to let the metal rise to the tuyere opening, and would not be especially objectionable if it entered them temporarily, as means are usually provided to introduce a bar to clean out any tuyere which would become obstructed.

X Q. 28. What I want to know is, what a good practical cupola furnaceman would do with a hearth that deep, 16 inches; would he always let the metal rise to the top and enter the tuyere openings or would he naturally tap before it raised that high, and if so, at about what height would he naturally tap?

A. In general foundry practice, especially in machinery foundries, the taps vary in weight, from the maximum content of the hearth, to any minimum fixed by the size of the ladle to be filled. In a 48-inch cupola, such as the one in question, the taps might range from a maximum of over two gross tons, to a minimum of about 2,000 pounds. A less quantity than, say, 2,000 pounds, would require very rapid work in tapping and stopping in, as the cupola melts about 200 pounds to the minute.

X Q. 29. Now answer the last question.

1000 *10 A. A practical cupola-tapper would not allow the metal to get to the tuyeres as a regular practice. If he were tapping maximum taps, he would tap sufficiently before the time the metal would reach the tuyere to prevent it being obstructed. About a 12-inch column of metal would be a safe height to run to in case it were left to the cupola-tapper to decide what quantity he should tap.

X Q. 30. Suppose there was no question about the matter except to get the metal out of the cupola in running the cupola most easily, and that the ladle was always ready to receive the metal from it; to about what height would the cupola-tapper naturally let the metal get before tapping?

A. He would not govern himself at all by the height of the metal, but by its quantity. In the case of this cupola, he would tap about once every ten minutes, say 2,000-pound taps, as being not too frequent.

X Q. 31. In measuring this cupola at the Whitney works, did you measure it above or below the tuyere openings to ascertain this diameter?

A. I measured it below the tuyeres, the lining being a practically true cylinder as determined by the eye.

X Q. 32. Was it apparently about the same diameter above the tuyeres?

A. At and somewhat above the tuyeres the parallelism continued; several feet up above the tuyeres and extending to the charging door above, the walls were somewhat worn by the stock and were therefore considerably larger. I did not measure it there.

X Q. 33. Well, the outside diameter of the cupola was apparently the same throughout its height, was it not?

A. Evidently to me it had been lined parallel to the charging door, but having been in use a considerable time, as evidenced by the wear, the upper part became undesignedly larger. The cupola shell was parallel up to the charging floor.

1000 *11 X Q. 34. In the ordinary working of a cupola, what supports the different charges of iron and fuel which fill up the cupola shaft?

(Objected to as not proper cross-examination.)

A. A properly filled cupola is filled with fuel from the bottom to some distance above the tuyeres before any metal is charged on it. Then alternate charges of metal and fuel are superposed to any height the cupola will hold. Under these conditions, part of the fuel in the bottom is supported on the bottom of the hearth. Above that the support is taken from the walls. The "angle of support" of material in the cupola is very flat, which is to say that after a few feet of material has been put in the cupola producing a given weight per square foot of bottom, any additional height can be put on up to hundreds of feet if need to without increasing the pressure on the bottom of the cupola. This is especially so when the cupola is

in operation, as evidenced by the very loose condition of the fuel at and above the tuyeres in the melting zone.

(Counsel for complainant here enters an objection to questions 22–30, inclusive, as not proper cross-examination.)

X Q. 35. From your last answer, I would understand that in the regular working of the cupola some fuel is resting on the bottom of the hearth and serves as a support, in part in least, for charges of fuel and iron above the hearth; is this correct?

(Objection continued.)

A. You misunderstand my reply, which especially refers to charging a cupola before any iron is melted. At that time, the bottom of the hearth does support the fuel, at least some moderate depth of it, but as stated before, when molten iron passes to the hearth the fuel is floated up clear of the bottom, which is then subjected to the weight of the metal contained and the fuel which is buoyant therein.

X Q. 36. Do you mean to swear that in the regular and continuous working of cupolas there is not some fuel resting on the bottom of the hearth, which fuel supports, in part at least, the charges of fuel and iron above the hearth? Please answer this yes or no.

1000 *12

(Objection continued.)

A. When the cupola has been drained of liquid metal, then the fuel rests upon the hearth, but as soon as there is enough liquid metal to submerge the bottom lumps they are raised from the bottom, and the bottom is then clear of fuel.

X Q. 37. Do you mean to swear that the fuel which rests upon the bottom of the hearth does not support, in part, at least, the charges of fuel and iron above the hearth? Please answer yes or no.

(Objection continued.)

A. In the practical operation of the 48-inch cupola in question, I am firm in my belief that not one ounce of the unmelted iron and the fuel mixed with it is supported by the bottom of the hearth.

X Q. 38. Can any one tell how much solid fuel is held within the hearth and below the tuyere openings in the ordinary working of a cupola?

(Objection continued.)

(As to the objections raised to Q.'s 34–37, the attention of the court is called to the witness' answer — X Q.'s 18 and 19 as showing the way he calculates the amount of liquid iron held in the hearth of the Whitney cupola.)

A. Not with exactness. I have indicated before that this would be variable, influenced by character of fuel, rate of combustion and ferrostatic pressure of liquid metal in the hearth. Mathematics give the size of the hearth, and the weight of a given volume of

fuel and liquid metal being known, practice supplies the data to approximate the quantities. The practice I refer to is the use of the tapping bar and the use of the sight-holes at the tuyeres, the former indicating that the fuel is floated up from the hearth in a bath of liquid metal, and the latter enabling one to see
1000 *13 the looseness of the fuel mass under combustion at the tuyere zone under the superposed mass of the charges above.

X Q. 39. When you visited the Whitney works in the spring and summer of 1897, did you at any of the visits take any other measurements than those taken of the cupola as shown in "Exhibit Fry Drawing of Whitney Crucibles"?

A. During my visit in the spring to settle a controversy with Mr. Whitney, Junior, then employed in the office of the works, as to the capacity of the distributing ladle, I measured it to verify my estimate of its capacity.

X Q. 40. What were the measurements that you then took?

(Objected to as not proper cross-examination.)

A. I took very roughly the cubical content and reduced that to tons of iron.

X Q. 41. Please state what the measurements were that you took of that ladle.

(Objection continued, and notice is given that any further testimony on this line as to the dimensions of the ladle must be considered as testimony on part of respondent, and counsel for respondent by this line of examination makes the witness his own.

Defendant's counsel replies that the witness was examined in chief as to the measurements taken from part of the Whitney plant, namely, the cupolas, and calculations as to weight made therefrom; that he admits having taken measurements of other parts of the plant, namely, the receiving ladle, and that it is perfectly competent and proper on cross-examination to test the witness' way of making calculations and the accuracy of the same by questioning him as to the measurements taken from the ladle; that in addition to this, he has been examined as to the condition of the plant as he saw it and as to the photograph showing the plant which includes this ladle, and even for this reason the cross-examination is proper; while it is hardly to be supposed that complainant's counsel
1000 *14 would object to the witness giving his measurements of the ladle when he had himself inquired as to its capacity when the witness was first called in this case.

Counsel for complainant states that the cupolas as to which the witness has testified are still in existence, supposedly in the condition when the witness examined them, and that the question as to any prior measurements of the ladle is but a crude way of testing the veracity of the witness, it not appearing that the ladle is any more accessible than the cupola. It is sufficient to say that the ladle or the use thereof was not even incidentally referred to in the examination-in-chief, and the reasons given by counsel for respondent appear to be a mere cloak to the purpose of the question.

Defendant's counsel asks whether complainant's counsel intends *by* the statement just made to be a recognition of defendant's right to examine the cupolas and the receiving ladle and produce evidence as to their present condition in answer to that produced by the testimony of this witness.

Counsel for complainant replies that the question as to the witness' right to testify in regard to the ladle on cross-examination is the only question at point, and it does not appear that this feature of the apparatus can here or at any other time be called in question under the testimony of this witness taken in chief. It does not appear that the size of the ladle can in any way affect the witness' testimony as to the size of the cupola, or why counsel for respondent could have the right acceded to him to take testimony in surrebuttal merely because he asks improper questions on cross-examination.

Defendant's counsel notes that the question put to complainant's counsel has not been answered.

Counsel for complainant replies that if counsel for respondent desires to take testimony in surrebuttal he can apply to the court.)

1000 *15 A. The measurement of that ladle was an incident of the moment only. It is a roughly lined thing and contained some skull of iron and other debris of a foundry in repose. I rough-measured its average diameter and average depth near enough for my then purpose, reduced this to cubic feet and then rough-calculated the weight of a similar number of cubic feet of cast iron. When done, I threw the paper aside upon which I had made the rough calculation.

(Counsel for complainant does not concede to counsel for respondent any right to take testimony in surrebuttal of the testimony of this witness.)

X Q. 42. Can you not now remember either the diameter or the depth of that ladle?

(Objection continued.)

A. I cannot remember any figures of dimensions.

X Q. 43. Have you ever operated cupola furnaces with anthracite coal as fuel?

(Objected to as not proper cross-examination.)

A. Yes, with anthracite, with many grades of coke, and with charcoal. All of these fuels at the foundry of the Cambria Iron Co., prior to 1871. I have officially observed the workings also of cupolas working a mixture of coke and anthracite coal.

X Q. 44. Which is the heavier fuel of the three?

(Objection continued.)

A. I do not recall the figures of weight of coke and charcoal, but I know the weight of anthracite coal. It is my opinion that anthracite is the heaviest of the three fuels named for a given volume of the fuel lumps.

X Q. 45. You refer in cross-answer 15 to the platforms of a cupola plant, which you say are ancient; what do you mean by the platform?

A. There is a platform upon which the cupola-tapper stands to tap the cupola, a little below the level of the tapping hole. There is a charging platform a little below the charging door several feet above the other. As may be observed in the photograph of these Whitney cupolas, the superstructure is of cast-iron members, an engineering practice prevailing a good many years ago. Had this superstructure been erected within recent years, it would have been chiefly of wrought-iron or steel beams. The "paneling," which is indicated on the front of the platform, was a style very much affected by engineers of metallurgical construction twenty-five years ago, but not applied in modern structural work.

1000 *16

X Q. 46. Can you state what the shaft or apparatus above the ladle in those photographs is, and what is its purpose?

(Objected to as not proper cross-examination.)

A. It is a semi-cylindrical structure of heavy sheet iron, manifestly for carrying the heat of radiation from the metal in the distributing ladle to a point some distance above the charging platform, so that the metal chargers working there in the highly heated atmosphere incident to the cupola would not be subjected to the full radiant heat from the ladle below them.

Adjourned to meet Sept. 18, 1897, at 10.30 a. m.

PITTSBURGH, *September 18th*, 1897.

Met pursuant to adjournment.
Present, as before.

Cross-examination of Mr. FRY continued:

X Q. 47. In the regular operation of a cupola in melting iron, does the fuel and iron above the hearth form an arch, so that no support whatever is taken from the fuel at or below the tuyeres?

(Objected to as not proper cross-examination.)

A. The unmelted iron and fuel mixed with it is above the tuyeres. With anthracite fuel, it would normally be about two feet above the tuyeres. With coke fuel, about three feet above the tuyeres. This because the carbon of the porous coke unites more readily with the oxygen of the blast than does the carbon of the denser anthracite. This stock, consisting of unmelted pig and fuel mixed with it, takes practically no support from the fuel below the point of fusion, for below that point we have a mixture of fuel in incandescence and liquid iron dropping regularly downward and not under pressure from the superposed stock above. The fuel below the point of fusion is a quite loose mass and not under pressure.

1000 *17

X Q. 48. You said yesterday that you could not remember any

of the figures of dimension of the ladle at the Whitney plant. Please examine the drawings of the Whitney plant "Defendant's Exhibit Nos. 2, 3 and 4," and taking the scales given thereon, calculate the holding capacity of the receiving ladle shown on those drawings.

(The question is objected to as not cross-examination, the ladle and dimensions thereof not having been referred to on direct examination. The cross-examination of this witness as to other matters has already been full, and this question opens up a new line of testimony on part of respondent, in spite of the fact that the witness has been called by the complainant.)

A. On examination of the drawings referred to, I find that the lines indicating the lining of the ladle are not drawn in conformity with those that would represent its condition at the time I examined it. If the ladle were lined as shown in the drawings exhibited, its safe-holding capacity would be very nearly exactly 34,292 pounds. I have a distinct recollection that the lining is not only thicker throughout than shown, but is proportionally much thicker below than above, which would be a proper way of lining, because a ladle lined as shown on these drawings would be too nearly parallel and therefore difficult to "scull out." In making this calculation I assumed that the ladle is filled to within 3 inches of the top, which is as full as would be safe in handling it to pour the metal from it.

1000 *18 X Q. 49. Please state what the dimensions of the ladle were on which you based your calculations?

(Same objection.)

A. From measurement of the drawings referred to, I have calculated the capacity of the ladle as equal to that of a cylinder 56¼ inches diameter and 53 inches deep.

X Q. 50. Take the outside dimensions of the receiving ladle shown in "Defendant's Exhibits Nos. 2, 3 and 4;" do they correspond approximately with what you recollect to be the outside dimensions of the ladle which you saw at the Whitney works?

(Objection continued.)

A. I made no measurements of the ladle shell. My impression is that there is more taper to the shell than is shown in the drawings referred to, and this impression is strengthened to almost a feeling of certainty by the appearance of the ladle shown on "Complainant's Exhibit Photograph of Whitney Cupolas." Generally speaking, I would express the opinion that the dimensions of the drawings do not greatly misrepresent the actual size of the ladle shell.

JOHN E. FRY.

1000 *19 *Order as to Surrebuttal.*

And now, to wit, October 23rd, 1897, the above motion for taking surrebuttal testimony on the part of defendant having been argued

and duly considered, defendants given leave to offer in evidence the publication in London Engineering of Jan. 8, 1884, and also a publication in the Journal of the Iron and Steel Institute of 1891, vol. 2, pp. 76–92, subject to complainant's objection that the same is immaterial, being subject to the date of the patent in suit; evidence as to the capacity of the ladle at the Whitney foundry, to be produced as agreed by counsel, the motion is denied as to taking further testimony, showing recognition of mixing at the works of A. Whitney & Son.

M. W. ACHESON, *Cir. Judge.*

Defendant's Surrebuttal.

Surrebuttal evidence for defendant, taken pursuant to order of court, dated October 23, 1897, at the office of Kay & Totten, Pittsburgh, Pa., on Saturday, October 30, 1897.

Present: James I. Kay, Esq., for defendant, and T. W. Bakewell, Esq., for complainant.

Defendant's counsel offers in evidence printed publication from London Engineering, dated January 18, 1884, on page 56 thereof, entitled "Stewart's cupola," constructed by Messrs. Thwaites Brothers, Bradford, together with the drawing referred to therein. Also an article found in the Journal of the Iron & Steel Institute for the year 1891, vol. 2, pp. 76 to 92, entitled "On the elimination of sulphur from pig iron," by Joseph Massanez, together with the discussion on the same.

Complainant's counsel admits that the said publications were published at the dates shown in them. He objects, however, to the said article "On the elimination of sulphur from pig iron" as immaterial and being subsequent to the date of the patent in suit.

1000 *20

It is hereby stipulated between counsel that the report of J. S. Robeson to Kay & Totten, dated Oct. 26, 1897, concurred in by John E. Fry, relating to measurements of the receiving ladle in front of the Whitney cupola, together with the sketch showing the dimensions of the same and calculations based on different thicknesses of lining, signed by said J. S. Robeson and John E. Fry, marked Exhibit Measurements Whitney Ladle, shall be filed in the cause with the same force and effect as if the said J. S. Robeson and John E. Fry had testified as and in the words stated by them respectively in the said report and sketch.

The foregoing offers are made in pursuance of an order of court made in this cause on Oct. 23, 1897.

JAMES I. KAY,
Counsel for Defendant.
BAKEWELL & BAKEWELL,
Counsel for Complainant.

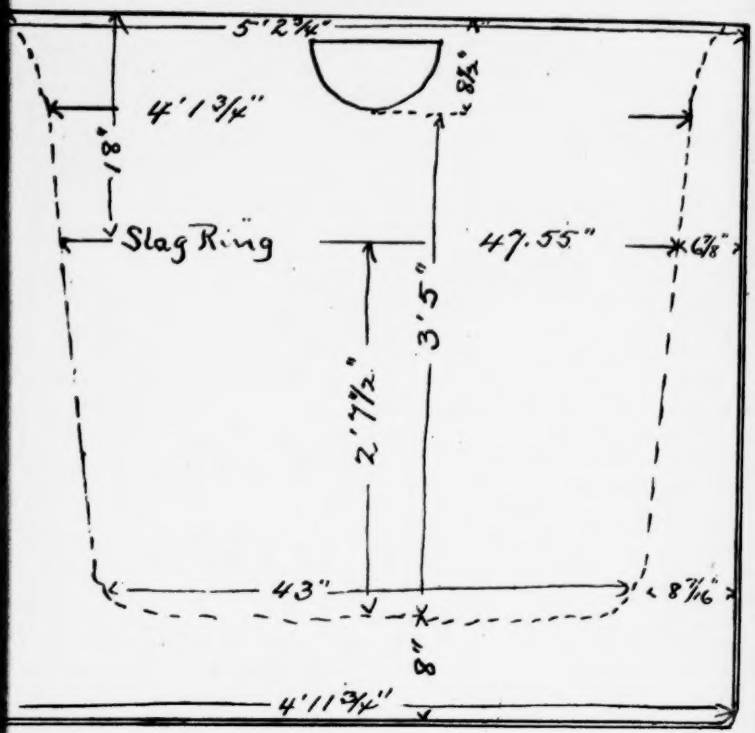
Defendant closes its surrebuttal evidence.

Whitney Ladle as Measured by J. E. Fry and J. S. Robeson, October 26th, 1897.

Top circumference, outside 16′ 6.″

Bottom circumference, outside 15′ 8½.″

Shell ⅜″ thick.



Carnegie Steel Co
or
Cambria Iron Co
} ℔ 1000 @ 22

1000 *21 "EXHIBIT MEASUREMENTS WHITNEY LADLE."

PHILADELPHIA, Pa., *October 26th*, 1897.

Messrs. Kay & Totten, 96 Diamond street, Pittsburgh, Pa.

GENTLEMEN: In company with Mr. John E. Fry, I have this morning visited the works of the Whitney Car Wheel Co., 16th and Callowhill streets, Philadelphia, and examined and measured the receiving ladle standing in front of the cupolas and already referred to in this case.

The ladle appears to be in the same condition as when last used and the following figures show the closely approximate dimensions inside of the lining and skull, and the quantity of metal it would hold when full, and also when last used.

Vertical height from bottom to lower edge of pouring lip, *i. e.* greatest possible depth of metal, 41 inches.

Vertical height from bottom to slag ring, *i. e.* depth of the last batch of metal in the ladle, 31½ inches.

Diameter at bottom, 43 inches.

Diameter at lower edge of pouring lip, 49¾ inches.

Diameter at slag ring, 47.55 inches.

These figures show that the last batch of metal in this ladle weighed 13,346 pounds ($5\frac{2146}{2240}$ tons), and that its full capacity, as at present lined and last used, would be 18,245 pounds ($8\frac{325}{2240}$ tons).

In making these calculations the cubic inches of capacity were multiplied by the factor 0.263 to ascertain the contents in pounds avoirdupois.

Yours truly, J. S. ROBESON.

N. B.—The foregoing statement of dimensions and contents of the Whitney receiving ladle is absolutely correct.

JOHN E. FRY.

(Here follows diagram marked p. 1000 *22.)

1000 *23 This ladle can hold as at present lined and with the skull now in it, 18,245 lbs.

The last batch of metal in it weighed 13,346 lbs.

If this ladle was lined only 5″ thick, it would hold 23,443 lbs.

If this ladle had a lining 5″ thick on the bottom and 3″ thick on the sides, it would hold 27,236 lbs.

The above measurements and calculations are correct.

J. S. ROBESON.

Messrs. Kay & Totten, Pittsburg, Pa.

DEAR SIRS: The undersigned fully agree with Mr. Robeson as to the accuracy of dimensions on the above sketch of the Whitney ladle, and to the calculations as to its capacity and the content of iron when last used; but does not endorse the speculative text above, relative to a supposed change of lining thickness.

Very truly yours, JNO. E. FRY.

Philadelphia, Pa., Oct. 28, 1887.

1000 *25 *Petition for Disclaimer.*

The honorable judges of said court:

The petition of this complainant, The Carnegie Steel Company, Limited, respectfully represents:

That your petitioner has this day mailed to the United States Patent Office for filing under the provisions of the statute in such case made and provided, a disclaimer to certain parts of the specification of the letters patent in suit, a copy of which disclaimer is hereto annexed as a part of this petition.

The petitioner avers that at the hearing of this cause it was taken by surprise by the argument of the defendant that the portions of the specification now disclaimed enlarged the scope of the invention of the said letters patent beyond what your petitioner believes to be the import of the claims thereof.

Your petitioner therefore prays that said disclaimer or a certified copy thereof may be introduced in evidence in this cause as part of complainant's record herein.

THE CARNEGIE STEEL COMPANY,
LIMITED,
By BAKEWELL & BAKEWELL,
Its Attorneys.

Disclaimer.

To the Commissioner of Patents:

Your petitioner, The Carnegie Steel Company, Limited, a limited partnership association under the laws of the State of Pennsylvania, and having its chief place of business at Pittsburg, in the county of Allegheny, Pennsylvania, represents that in the matter of a certain improvement in methods of mixing molten pig metal, for which letters patent of the United States No. 404,414 were granted to William R. Jones, of Braddock, in the county of Allegheny, in said State, on June 4th, 1889, the exclusive right, title and interest in which are vested in your petitioner by virtue of a certain
1000 *26 assignment from Harriet Jones, executrix and residuary legatee of the estate of the said William R. Jones, deceased, bearing date October 24, 1889, and recorded in the United States Patent Office in Liber —, page —, of assignments of patents, that it has reason to believe that through inadvertence, accident of mistake, and without any fraudulent or deceptive intention, the specification of said letters patent is too broad, including more than the invention of said patentee.

Your petitioner, therefore, intending to limit the scope of said letters patent to the mixing of molten metal preparatory to its further treatment, hereby enters this disclaimer to those parts of the specification which are in the following words, which your petitioner desires to erase from said specification: On line 83 to line 91 of the first page of the said specification the words " for example, by merely receiving in a charging ladle a number of small portions

of metal taken from several ladles or receiving vessels containing crude metal obtained at different times, or from different furnaces, the mixing being performed merely by the act of pouring into the charging ladle, and other like means may be employed."

On page 1, the 100th, 101st, and 102d lines, and lines 1, 2, 3 and 4, on page 2, as follows: "My invention is not limited to its use in connection with converters, since similar advantages may be obtained by casting the metal from the mixing vessel into pigs, for use in converters, puddling furnaces, or for any other uses to which pig iron may be put in the art."

On page 2, lines 127, 128, the words "or the metal is cast into pigs or otherwise used."

THE CARNEGIE STEEL COMPANY, LIMITED,
By L. L. PHIPPS, *Second Vice-President.*

Witnesses:
H. M. CORWIN.
L. A. CONNER, JR.

1000 *27 *Opinion of the Court.*

(Filed Sept. 5th, 1898.)

BUFFINGTON, *J.*:

This case concerns the art of steel-making. As the difficulties which the patent sought to obviate in that art arose in the Bessemer process and its practical application has been wholly therein, an account of such process and its relation to, and effect on, the art would seem proper if not indeed indispensable to a proper understanding of the case. And as this patent underlies, and in a measure possibly dominates the successful commercial converting of Bessemer steel by the direct process, the importance of the question involved must be a sufficient warrant for this unusually lengthy opinion. Tersely stated, the Bessemer process consists in blowing air through molten pig iron placed in a refractory lined vessel called a converter, whereby the oxygen combines with, and burns out, the carbon and silicon. It was probably the most potent factor in broadening the scope of the steel industry, cheapening its product, making possible its use in new and wider fields and substitution for iron. While the foundation of this advance is based on Bessemer, improvements were made by others. Touching only on such as are pertinent here, we note that when iron was thoroughly decarburized a certain necessary amount of carbon was restored to the metal by Muchet's method of introducing ferro-manganese or spiegeleisen. With the Bessemer invention was soon seen the possibility of making steel by what was known as the direct process; that is, taking the molten metal direct from a blast furnace and subjecting it in a fluid state to the Bessemer process. The immense saving in both labor and plant appliances in case this could be successfully done were self-evident; but grave difficulties in the way of such use soon became apparent and threatened, unless met,

enforced abandonment of such direct process. What these difficulties were will appear from a study of the thermal
1000 *28 and chemical, or quasi-chemical, elements of molten-metal treatment.

From the heat-yielding capacity of silicon the high temperature needed for heating, and keeping heated, the fluid in the converter was obtained. Such high stage of heat was imperative from the fact that as the fluid, by the consumption of carbon and silicon, approached the condition of pure iron, its melting point rose, and unless a correspondingly high temperature was kept up the fluid grew thick or pasty, an objectionable condition. Much of the heat generated by carbon oxidation passed off with the carbonic oxide gas, but the oxidized silicon formed slag, which remained in the converter, and the intense heat caused by the burning of the silicon was thus retained and utilized. Its varying degree, however, was a source of serious trouble. Such trouble arose in this way: If the metal contained a high percentage of silicon the resultant heat was proportionately great. If such heat was excessive and not controlled or neutralized, overblown or wild heats of steel resulted, which could only with difficulty be deoxidized with manganese, and which likely resulted in a bad product. On the other hand, if the fluid mass was too low either in initial temperature or in silicon percentage, these factors, if not corrected, produced chilled heats or scrap. To neutralize or convert as far as possible these adverse, unfavorable conditions was the province of an adept, skillful and expert blower or converter man. That such qualities were indispensable will appear from attendant conditions. The converter reactions were rapid, the entire operation lasting but ten minutes. The peculiar appearance of flame jetting from the converter mouth was an index to the blowerman of the thermal character of the charge. If he thought it too hot he added varying, but sometimes large, quantities of cold steel scrap, which absorbed the heat necessary to melt it, and so reduced the average temperature of the mass. Steam blown in with the air through the tuyeres was also used to pro-
1000 *29 duce the same effect. By reducing the amount of scrap, or omitting it altogether, varying conditions of heat were met. An excessively cold heat might also be "side-blown" or the converter turned on its side so that a portion of blast passing over the surface increased the heat by burning the iron itself. This, however, greatly increased waste. The situation called for quick decision and rapid execution, and a mistake in either direction spoiled the steel. Moreover, one converter charge was neither an index of its successor or a sequence of its predecessor. Each one was unique in character and required individual and varying treatment. This arose from the shifting, unaccountable, and seemingly arbitrary working of blast furnaces, or, indeed, of a single furnace. As illustrative of such workings we quote, as fairly representative, the testimony of Mr. James Gayley, superintendent of complainant's blast furnace department, who says:

"The conditions under which a blast furnace is operated are such that the slightest change in composition of the ore, fuel or the lime-

stone will produce a respective change in the composition of the metal, and even so slight a change in conditions as represented by a change in the content of moisture in the atmosphere produces, all things beings considered, the widest fluctuations in the composition of the pig metal; and inasmuch as the conditions of the atmosphere are beyond control, so it is impossible to control the product of a blast furnace in point of uniformity of composition. * * * For instance, a slight change in the composition of the material charged into the furnace produces an irregularity in silicon in the metal. This variation is again produced by a change in the volume or temperature of the air that is blown in, or by a change in the composition of the slag, and also in a very marked manner by the least change in the content of moisture in the atmosphere, as, for instance, a day in which the atmosphere is very humid, the moisture entering the furnace with the blast requires an undue
1000 *30 expenditure of heat in the zone of combustion and produces a metal that is low in silicon. Again, on a day when the atmosphere is very dry, the opposite conditions exist, and there is produced a metal unusually high in silicon, either of which is undesirable in Bessemer steel operations. * * * Blast furnaces of the same size and interior shape and charged with the same mixture and weight of ores will vary in the character of metal produced just as much as if all the above conditions were different. * * * In our furnaces of standard capacity we blow 35,000 cubic feet of air per minute. If the moisture in the air is one grain per cubic foot, on this basis we blow in about 25 gallons of water per hour. The average content for the year is about 5 grains of moisture in a cubic foot of air, which would represent 125 gallons of water per hour going into the furnace in the condition of aqueous vapor. As is well known, the humidity of the air may change decidedly from day to day; as, for instance, in summer time while today might have 5 grains of moisture in a cubic foot of air, tomorrow our hydrometer might show 8 grains, and sometimes 10 grains, thus changing suddenly from 125 gallons of water per hour to 200 or 250 gallons. This moisture must be dissociated in the hearth of the furnace and absorbs heat rapidly, causing violent fluctuations, and unless quickly perceived and controlled by manipulation of the hot blast. The change in the humidity of the air is the most troublesome element to contend with in the manufacture of pig iron, and the margin or surplus in the heating capacity of the stoves is not always sufficient to meet it."

These varying conditions, results and product incident to blast-furnace practice, produced corresponding irregularity in the working of converters. Cold blow followed hot blow and *vice versa;* the conditions were so varying that it was difficult for the converter-men to correct the heats, and the workings were so uncertain that it was impossible to produce a uniformly good quality of steel.

1000 *31 That these grave difficulties existed and bade fair to defeat the use of the Bessemer direct process is shown, first, by the resort of manufacturers to the more expensive cupola

practice; next, by the literature of the art, and lastly, by the proofs in the case.

As molten pig metal in a converter is the base of Bessemer steel, and as pig metal at high temperature is tapped in that state from blast furnaces, it requires no argument to show that the direct process is the natural and logical theoretical one to adopt in economic Bessemer steel making. Rehandling and reheating are done away with. When we consider the vastness of the product and that the cost of these items, even when done on a large scale, is possibly sixty-odd cents per ton, we gain some idea of the economic advantages of the direct over the non-direct or cupola method. In addition to which metal in remelting is subjected to objectionable contamination from coke. The direct process was one of the original ideas of Bessemer, and he purposed the use of his process in that way. The theoretical possibilities of it and its great economic elements have proved a constant temptation to its adoption, but in spite of this the practical obstacles in the way of its successful practice led quite generally to the use of the indirect or cupola system. In it the product of blast furnaces was cast into pigs; these when cold were assorted, selected and remelted in cupolas. By this means a molten product of the desired composition, substantially uniform in character and suited for successful converter treatment, was secured. But the system involved the necessary rehandling and remelting of the product, maintenance of a cupola system, and the contamination of the metal with sulphur emitted from the coke used in remelting.

That serious obstacles to the use of the direct process in connection with Bessemer converters existed is shown, as we have said, by the literature of the art. In 1872, Mr. Z. S. Durfee,
1000 *32 himself a distinguished metallurgist, in the specification of U. S. patent No. 122,312, offered in evidence by the respondent, clearly states these obstacles, and says by reason of them the direct process has been abandoned by many proprietors for the non-direct, in spite of its greater expense. His language was—

"In the manufacture of steel by the pneumatic or Bessemer process a great saving of fuel and iron, of wear and tear of furnaces and of labor would be effected were it possible to make uniformly good products of the desired temper by converting the crude iron immediately it is tapped from the blast furnace in which it is made. This plan has been, and may still be, practiced to a considerable extent; but it has been found that by reason of the irregular working of blast furnaces, and the consequent varying character and quality of the crude iron produced, it was always very difficult, and in most cases impossible, to secure such uniformity in the converted metal as was essential to success in the business. Hence, at several establishments where the plan of taking the fluid iron as it was tapped from the blast furnace and pouring it at once into the converter had been practiced, it has been abandoned, the proprietors preferring to incur the expense of handling and remelting the crude iron after it had been cast into pigs in order thus to secure the ad-

vantage of carefully selecting and mixing the materials for each charge to be converted."

In "Engineering," a London publication of 1877, appears an article by Messrs. Smith and Holley, describing the construction of the Vulcan works at St. Louis. Mr. Holley, who designed them, was one of the most noted of American steel engineers, and was subsequently employed by the American Bessemer manufacturers to study and report advances in the art. In this article Mr. Holley, in describing the plant, says it is arranged for the direct process.

Mr. J. E. Fry, who was employed at the works from
1000 *33 1881 to 1883, says the cupola system alone was employed, the Holley appliances for the direct process remained unused where they were constructed in the works, and the other needed apparatus was never completed.

The discussions of the scientific societies of an art may be taken as a fair index of most advanced theoretical current thought and practical result. A careful perusal of the proceedings of such bodies is instructive in those regards. The Journal of the Iron and Steel Institute of Great Britain, at its London meeting of 1874, contains a discussion at considerable length of the direct process as applied to Bessemer converters. A careful examination of these discussions satisfies us, first, that the members were keenly alive to the advantages and economies of the direct process; second, they recognized the obstacles in the way of such use by reason of the eccentric character of furnace working and product; third, while they hoped it would be, they recognized the problem had not then been solved. The consensus of opinion was fairly summed by one of the delegates, Sir James Ramsdell, who said, "With reference to Mr. Williams' remarks as to the proposal for running the fluid iron direct into the Bessemer converter, the subject has been under the consideration of the Barrow Company for some time; in fact they had tried some practical experiments, and arrived at the conclusion, as far as their knowledge went, it was a very doubtful undertaking. Certainly they could not produce the quality of steel that was necessary to satisfy the market at that time."

In the president's address certain pending experiments in the line of the direct process were referred to; the use by the French of the direct process commented on (a success, by the way, attributable to the highly manganiferous character of the ore used, and not to any causes pertinent to the patented process now under consideration), and urging of progress in that regard
1000 *34 by English manufacturers. In an article on Bessemer works, Sir Lowthian Bell, a recognized authority in the metallurgical world, summed then present conditions by saying, "So far as I know, the Americans, like ourselves, have done nothing in imitating the French by running the iron from the blast furnace direct into the converter." A perusal of these papers shows the keen appreciation by the English manufacturers that they must find some way of using the direct process. This was emphasized by the paper read by a Brussels engineer on the successful manufacture of Bessemer steel at the Seraing works by the

direct process, where the manganiferous quality of the ore used was such that no spiegel had to be introduced at the end of the blow. It was recognized that these favorable conditions did not exist in England, and that some other way must be devised of overcoming these recognized obstacles.

In vol. 5 of the transactions of the American Institute of Mining Engineers, 1876–1877, an elaborate paper on the history of Bessemer manufacture in America was read by Mr. Robert W. Hunt. In it he attributed much of the then advance to Mr. Holley, and in recounting his share said, "He substitutes cupolas for reverberatory furnaces; these points," he says, "Cover the radical features of his innovation." This brings us to considering the Holley report of 1877, which deserves careful attention, both from its importance in the literature of the art, and also from the fact, as we shall see later, that it is cited and strongly urged as an anticipation of the patent in suit.

Mr. Holley's position in the art was unique. He was a metallurgical engineer of distinction and was employed as consulting engineer by practically all the American Bessemer manufacturers. It was his duty to yearly visit the European works, keep in close touch with the advance of the art and suggest desirable changes. From respondent's proofs we learn that the reports of Mr. Holley to the American manufacturers "received most careful consid-
1000 *35 eration at their hands, and from time to time, and when deemed advisable, the American practice was altered in view of the information so furnished. These reports were regarded by the various organizations as most valuable ones, and upon their receipt were given most serious consideration." From this and numerous other references in the proofs, we are warranted in regarding Mr. Holley's report, so far as it went, as a careful, just and expansive résumé of then conditions. A study of the report shows conclusively that in Mr. Holley's judgment, the direct system, at that time, if not a failure, was at least imperfect and incomplete; that the source of difficulty was clearly located and fully understood; that while the general lines on which the remedy was to be sought were indicated and the desired end stated, the means by which it was to be done were not pointed out, and that the indirect or cupola system was deemed the preferable and the only practicable practice in the then state of the art. In these respects the report utters no uncertain sound. He says:

"Running iron from the blast furnace directly into the Bessemer converter has now been practiced long enough in Great Britain to test the commercial advantages of the system, to show its incompleteness, and to suggest a remedy." What that incompleteness is, is accurately stated.

"It should appear, I think, from the facts stated—

"First. That we are not, in the present state of the art, incurring an important loss by selecting and remelting pigs. This remark will probably apply even to those works which include a considerable and convenient blast-furnace plant. If with a less experimental ore supply than we have, and a better average blast-furnace

practice than our own (although it may not be better than our best), and so great a number of furnaces that one or another may be relied on for approximately suitable pig—if with all these advantages the English works are in such serious trouble about silicon that they are devising expensive remedies in the way of mixing furnace products, then it seems reasonable to suppose that we, with our more experimental ores and less refined practice and fewer furnaces, should encounter still more serious embarrassments."

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That these troubles were present in the English practice is made clear. Thus, he says of the West Cumberland practice: "These savings amount to $1.25 gold per ton on rails but must be considerably more were it not for excess of scrap, due to the silicon running too low, and to second quality of steel, due to its running too high. * * * Although the results are constantly improving, it is admitted at West Cumberland that the cupola practice is still the best for special steel where great regularity is required."

In the Barrow practice he also reports the continued existence of the same trouble, and that any improvement is not from mixing, but from better blast-furnace practice. Thus, it is said, "While the Barrow ores have much more silica than those used at West Cumberland, and hence make a hotter blowing iron, there is considerable trouble from cold charges, and quite as much from waste and cold shortness, caused by too much silicon * * * with Barrow ores alone the silicon in the pig averages 3½ per cent. and may be kept pretty regular; but a varying quantity of varying Irish ores is also used, and these are said to cause the irregularity; whatever the cause, the silicon is constantly varying as much as 1 per cent., that is from about two to three per cent."

Even the Creusot practice, which he says is the best, and which, as we have seen, had the advantage of a high manganiferous grade of ore, was not wholly satisfactory. Thus, it is said, "Yet, with all the care taken at Terrenoire and at Creusot, with manganese as a heating element, there is more or less trouble from the variation in the temperature of the charges."

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As we read the proofs, there were at the time of this report no American Bessemer plants following the direct process. After an examination of all these foreign works, Mr. Holley advises continuation of the indirect or cupola practice. He advises, therefore, that his clients confine their efforts to increasing the uniformity and standard of blast-furnace practice and securing a more uniform product. By means of this they will obtain increased value for the pig sold and a cheapened product in what they used. These factors for raising the standard he had previously indicated as "more care as to the selection of ores, the size of ore and limestone, the distribution of materials in the furnace, the temperature of the blast and all elements of uniformity."

Now, practically summed up, Mr. Holley at the time saw in the best English and continental practice nothing to remedy the known and conceded defect in the system, viz., non-uniformity of product. It is clear that at that time the defect had not been practically met.

The mode of meeting it was pure theory. As he himself said, "Ores will never be uniform; hence uniform results in the Bessemer department can hardly be expected, unless a number of blast-furnace charges are mixed. This would seem to be the theoretical solution of the problem." Now, while it is true that Mr. Holley expressed in a general way his belief that this difficulty of non-uniformity could be met, it is equally true he disclosed no plan of doing it. Indeed, there was no inducement for him to do it for his clients, for he says, "we may congratulate ourselves that the direct-metal users have no advantage over us in the present stage of the art." It is therefore clear that as he then saw conditions he merely advised, as we have said, the adoption of better furnace practice in the cupola system as a preparatory step toward the ultimate adoption of the direct. The contention that he had then even theoretically shown how the mixing could be done is negatived

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by his own statement, "When the way to its successful adoption is demonstrated, the direct process will undoubtedly have great advantages, even over the present practice on the continent, which employs manganiferous ores. But until this large-scale mixing is developed, it should not appear that the use of our comparatively irregular blast-furnace metal, and more especially the use of part blast furnace and part cupola metal, can result in any substantial saving." These are words of future possibilities, not of already discovered practical processes which would anticipate a subsequent inventor in the enjoyment of the fruits of his genius. The disclosures or suggestions of Mr. Holley are to be judged, not in the light of subsequent development but of cotemporaneous practice, and tested by that standard we see no evidence of any process or means of solving the admitted difficulty. That such was the case is evidenced by the fact that Mr. Holley never used the direct process at the Vulcan works which he was then constructing, and in the next year, 1878's Journal of the Iron and Steel Institute, it was stated, in a discussion showing the improvements in the cupola practice, that "Mr. Holley had of late taken very decided views on that subject, and had quite come to the conclusion that the hoped-for advantages had not resulted altogether, because, you had not absolutely in your control to get a uniform metal from the blast furnace." While we thus have from the statement of Mr. Holley, whom both sides concede was a master of the situation, the confession that securing the necessary uniformity of product for the direct process had not then been solved, it would seem scarcely needful to go into the patents of the prior art to find in them a theoretical solution which Mr. Holley's ability, knowledge and employment had not as late as his report led him to find there or elsewhere.

In 1882 the direct process was installed by the Carnegie Company at their Edgar Thomson works near Pittsburgh. The proof is clear that the grave known difficulties of the non-

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uniformity in the direct process were met for several years. Mr. Carnegie, of that company, says: "There were both advantages and disadvantages. The advantages were

that we got less sulphur in the metal by the direct process and we also thought that we would save cost; but the disadvantages were so great that we often debated whether to abandon the process or not. We found it impossible to get uniform quality of rails as well as by the cupola method; we found that we could not take metal as the furnaces made it. We tried to fill the furnace cars partly from one furnace, partly from another, but this was not found practicable; trying to tap furnaces at irregular times producing irregular working."

Mr. Gayley, testifies of the difficulties encountered. He says:

"Under this system of operation, we found that the work in the Bessemer department, compared with the former practice by the use of cupolas, was very irregular. One cast of iron would be quite low in silicon and would cool off the converters to such an extent that the next cast would have to be taken from a furnace that was higher in silicon than was desired in order to restore the heat in the converter. Sometimes a few casts might be very close in their composition and the results would be very good, but the general experience showed that great variation in composition was the rule, and so great was this variation that special men were employed at the Bessemer department at high salaries in order to devote their time to the judging and correcting of this variation in temperature induced by the variation in silicon, to overcome the bad results that were obtained, and, in addition, the force of chemists had to be doubled, and various other expenses gone to in the endeavor to overcome this great variation in composition. For instance a slight change in the composition of the metal charged into the furnace produces an irregularity in silicon in the metal. This variation is again produced by a change in the volume or temperature of the air that is blown in, or by a change in the composition of the slag, and also in a very marked manner by the least change in the content of moisture in the atmosphere, as, for instance, a day in which the atmosphere is very humid, the moisture entering the furnace with blast requires an undue expenditure of heat in the zone of combustion and produces a metal that is low in silicon. Again, on a day when the atmosphere is very dry the opposite conditions exist, and there is produced a metal unusually high in silicon, either of which is undesirable in Bessemer steel operations. * * * Our analyses showed that each ladle in the cast varied from each of the others, and sometimes within very wide limits, and also that the average analysis, even from each furnace, varied to a great extent from the furnace from which metal was taken just before or after and that this variation in composition of metal going through the steel works produced great irregularity in practice by reason of the conditions being so variable; as, for instance, one cast of iron, or a ladle or two in the cast, might be of very low silicon content, producing a chilled heat of steel in the Bessemer department, causing a loss of metal and injury to the apparatus. In order to offset the ill effects that were produced, which consisted partly in cooling down the converters to a great extent, the next cast would have to be drawn from a furnace that

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was abnormally high in silicon. This was necessary in order to restore the heat in the converter and remove any scull that had been formed, and thus required the operators to work with metal that was widely divergent in composition and likewise in quality."

Mr. Julian Kennedy, a mechanical engineer of wide scientific knowledge and much practical experience in the use of the Bessemer process, who was called on behalf of the complainants, thus strongly set forth the difficulties in the use of the process:

"Ever since the invention of the Bessemer process it has been well recognized that great economies could be at-
1000 *41 tained by transferring the molten metal from the blast furnace to the converter without allowing it to solidify. Until within a few years, however, this direct process, as it has been called, has not been generally used. It is easy to see why this was the case. The fluctuations in the chemical composition of the metal from the blast furnace was too great to allow that degree of uniformity of product in the Bessemer steel produced from it, which is absolutely necessary in the case of steel rails, for example, which must be as reliable as human skill can make them, and where no reasonable expense can be spared to make them perfectly safe and trustworthy. A very few broken rails in a track, with the damage to property and human life which this might cause, would far more than offset any possible saving in a year's work, due to the use of the direct process. For this reason the practice, until within comparatively recent years, has been to cast the metal in pigs, then to analyze it and reject any portion not closely approximating a rigid specification in its chemical composition, and to select, mix and then melt the approved metal in cupola furnaces. By this means very great uniformity of chemical composition of the remelted metal can be obtained, and good and reliable steel made from it with regularity and certainty."

Mr. M. J. Dowling, now superintendent of the converting department of Jones & Laughlin, where the cupola or direct process is used, and formerly employed at the Edgar Thomson converting department, in both the direct and cupola systems, says:

"During my experience with the direct process the difficulties were, many more chilled heats and many more skulled ladles and much more scrap than with cupolas. * * * As far as my recollection serves me, I should say that the amount of chilled heats with the direct process over the cupola process would be fully
1000 *42 50 per cent. I have seen as many as 14 consecutive chilled heats with the direct process."

Mr. Perry D. Mackey, foreman of the Edgar Thomson converting works, and employed there since 1879, nine years of which he served as a blower, described the practical difficulties of the work in the direct process. In answer to the question, "Is it possible, practically, to run the converters without producing chilled heats, where there are sudden changes in the silicon of the furnace metal, and if not, why not?" said:

"No, you cannot do it. The reasons are the changes are so sudden and varying so greatly, that a blower is unable to keep pace with it. The consequence is, he will underscrap one heat, spoiling it by being too hot, the other he would overscrap, causing its conversion to chill. * * * On the other hand the direct iron is very irregular, varying from white iron, or low silicon iron, to as high as 4 per cent. silicon, making the converting mill very irregular and very unreliable. The variations being so great in iron of the one cast, it is an impossibility for the blower to follow it, and in consequence he has chilled heats and very bad material. Low silicon iron requires no scrap, while 4 per cent. silicon would require from 8,000 to 9,000 pounds of scrap. The variations between the two the blower regulates according to his previous heat, as I have stated before. Had he been using iron requiring from 8,000 to 9,000 pounds of scrap and prepared for his next heat the same amount of scrap, the consequence would be that he would have a chilled heat. What I mean by a 'chilled heat' is, a heat that would be a dead loss to the company."

Mr. WALKIN Y. WILLIAMS, now in charge of the converting mill of the Johnson Company, of Lorain, Ohio, and employed as foreman and scrapper at the Bessemer plant of the Edgar Thomson Company for nine years, testified of the work there as follows:

1000 *43 "Q. In the use of metal taken directly from the blast furnace, will you state whether sudden changes in the character of the metal made the scrapper apt to make mistakes in the amount of scrapping, and if so, will you please explain the same.

A. Yes; we were expected to keep an even temperature, and with the two extremes of hot iron and cold iron coming so suddenly it was almost impossible to keep them of an even temperature.

Q. What effect would such mistakes have been upon the steel?

A. The steel we failed to reduce to a proper temperature would become brittle and unsafe, while the extreme cold heats would make more scrap."

Mr. George Lauder, a member of complainant's company, testifies to the grave character of the difficulties his firm met in the use of the direct process. He says:

"During the whole period of the use of the direct process we had a great deal of trouble on account of the number of defective rails we made and the irregularity in quality of the first quantity of rails we sent out. At times this reached such alarming proportions that we frequently discussed the question whether it would not be advisable to return to the cupola practice. The only alleviation we had during that time was to use more cupola metal whenever the furnaces went off."

Mr. Kennedy, to whom reference was made above, testifies that during the time of his employment at the Bessemer works and as consulting engineer, the question of the extension of the Bessemer plant of the complainant company was taken up by Mr. Gayley

and himself. Speaking of a time when the direct process had been in use for several years, he says:

"After studying the results which had been obtained at the Edgar Thomson works and elsewhere in the use of the direct
1000 *44 process, I consulted with Mr. James Gayley, and we agreed that in the building of a new works it would not be profitable to use direct metal, but that on the contrary, the disadvantages resulting from the irregularity in the product were so great that it would be better to go to the expense of building and using cupola furnaces. We did not then perceive any means adequate to overcome these disadvantages."

The proof of these grave difficulties, challenging the successful commercial use of the direct process, is so convincing that they corroborate the statement of Mr. William Metcalf, a witness whose practical experience, scientific attainments, and high position in the American metallurgical world enabled him to know and speak with weight in his art. Our examination of the literature of the art and the proofs of this record warrant us in agreeing with his summary, which was:

"For some years previous to the development of the Jones apparatus and process, all the metallurgic world was crying out and studying and searching for the same method by which they could successfully and practically use the metal direct from a blast furnace in a Bessemer converter, to avoid the cost of remelting in a cupola and also the injury that the melting in a cupola does to the iron.

"The object in using iron direct from the blast furnace in the Bessemer process is twofold: First, quality, and second, economy; or *vice versa* as people look at those things. All of the evidence of the literature of the Bessemer process goes to show that for years there were serious efforts being made to devise a practical method of using the iron direct from the blast furnace, and to get rid of the serious trouble there is from the fact that a blast furnace is liable to change suddenly and produce an iron varying so much in silicon particularly, and also in carbon, as to cause very sudden changes in the
1000 *45 working of the iron in the converter, rendering it liable at one time to have the vessels and everything sculled by a cold heat, or have everything burnt out and ruined by a too hot and wild heat. The whole object then was to get some mean of the product of the blast furnace which would avoid these extremes. These extremes did occur in practice, as the records show, and were such as to practically eliminate the benefit which it was well known would exist if the metal could be used directly from the blast furnace."

In this state of the art, application was made for the patent in suit by Captain William R. Jones, now deceased, then superintendent of the Edgar Thomson Bessemer plant. He was a steel man of long experience, and in his special employment had full knowledge of the difficulties met in the use of the direct process at the Edgar Thomson works. Simply stated, Jones' idea was the creation and maintenance of a great pool of metal between the blast furnace and

converter plants, through which all incoming and outgoing metal must pass. By this means each converter charge from this homogeneous mass was so closely akin in heat and constituent parts to the one preceding and to the one following it, the differences were so gradual and regular, that it was an index to the converterman of the thermal and chemical character of the one to follow. To replace the withdrawn converter charges fresh additions of blast-furnace molten metal were constantly added. Now, while as we have seen from the proofs, these additions were non-uniform in heat and constituent elements, and each of them probably, certainly possibly, variant from the converter charge just drawn, yet their divergent qualities were, by the assimilating character of the dominant mass, toned and averaged to its character and were thus sheared of their capacity to harm.

To illustrate: If we take a mixing vessel containing 90 tons of molten iron, whose content of silicon is 2 per cent.; add to this a charge of ten tons of molten iron containing 4 per cent. silicon; we have a resultant mixture containing 2.2 per cent. of silicon. Now draw off ten tons from the mixer, and add 10 tons more containing 4 per cent. of silicon, we have a mixture containing 2.38 per cent. of silicon. By again drawing off 10 tons and replenishing with 10 tons more of iron containing 4 per cent. of silicon we have a mixture containing 2.54 per cent. of silicon. It is therefore plain that with a mixer thus operated, it is possible to have wide variations in the composition of the blast-furnace metal charges added, and at the same time the successive withdrawals for the Bessemer converter show quite small and gradual changes of composition. The heat of the detained mass is affected by the incoming charges just from the blast furnace, but the heat of such addition, whether relatively high or low, must mingle with, be modified by, and average with the heat of the larger and dominating mass.

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It will thus be seen that each individual incoming charge loses and merges its dangerous individuality (*i. e.*, its heat and constituent composition) in the average of the dominating mass, and the withdrawn charges are from such slow, shifting, average mixture. It is therefore apparent that each converter charge is an index in heat and composition of the one to follow. This simple, commonplace, practical principle, which after all is the underlying principle of the governor in the use of steam, and the fly-wheel in the regulation of power, Jones embodied in his process patent No. 404,414, issued June 4, 1889. Infringement is alleged of the second claim. The process, so far as this claim is concerned, is disclosed and described in the specification, and from it we quote. Having first stated, "That the primary object of my invention is to provide means for rendering the product of steel works uniform in chemical composition," the specification recites the fact of non-uniformity of blast-furnace product and the results produced thereby. As we read this specification it contemplates, as far as the claim under consideration is concerned, two disclosures, viz: first, obtaining a homogeneous mixture, and secondly,

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using such mixture as an effective means to avoid abrupt variations. As bearing on the first purpose, viz: obtaining a homogeneous mixture, the specification first recites the difficulties met with and which render such mixture desirable. In that regard it says:

"The consequence of this tendency of the silicon and sulphur to segregate or form pockets in the crude metal is that the product of the refining process in the converters or otherwise, in like manner lacks uniformity in these elements, and therefore causes great inconvenience and loss, making it impossible to manufacture all the articles of a single order of homogeneous composition. Especially is this so in the process of refining crude iron taken from the smelting furnace and charged directly into the converter without remelting in a cupola, and, although such direct process possesses many economic advantages, it has on this account been little practiced."

It then states how the homogeneous mixture is obtained, viz:

"For the purpose of avoiding the practical evils above stated I use in the refining process a charge composed not merely of metal taken at one time from the smelting furnace, but of a number of parts taken from different smelting furnaces, or from the same furnace at different casts, or at different periods of the same cast, and subject the metal before its final refining to a process of mixing, whereby its particles are diffused or mingled thoroughly among each other and the entire charge is practically homogeneous in composition, representing in each part the average of the unequally diffused elements of silicon and sulphur originally contained in each of the several parts of charges. By proceeding in this way not only is each charge for the refining furnace or converter homogeneous in itself, but, as it represents an average of a variety of ununiform constituent parts, all the charges of the converter from time to time will be substantially uniform, and the product of all will be homogeneous."

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The specification then describes the gist of the invention, viz: the process of using this homogeneous mixture as a controlling dominant pool. This is preferably accomplished by a large refractory lined, covered vessel, pivotally mounted and provided with an intake hopper and an outlet discharge pipe, so located that a considerable quantity of molten metal must constantly remain in the vessel. The description of the vessel, its mode of operation and functional purposes are thus set forth: "It consists of a covered hollow vessel * * * lined with firebrick or other refractory lining, which would be of sufficient thickness to retain the heat of the molten contents of the vessel and to prevent chilling thereof * * * may be of any convenient size, holding, say, one hundred tons of metal (more or less) * * * one end—the rear one—being considerably deeper than the other. * * * At the front end is a discharge spout, which is so located that the bottom of the spout is some distance above the bottom of the vessel—say two feet in a hundred-ton tank and more or less, according to the capacity of the vessel—the purpose of which is that when the metal is poured out of the spout a considerable quantity may always be left remaining and unpoured, and that whenever the vessel is

replenished there may already be contained in it a body of molten metal with which the fresh addition may mix. I thus secure, as much as possible, uniformity in character of the metal which is fed to and discharged from the tank, and cause the fluctuation in quality of the successive tappings to be very gradual. The mode of operation of the apparatus is as follows: When the vessel is in the backwardly inclined position shown in Fig. 1, it is ready to receive a charge of metal from the car 7.

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Before introducing the first charge, however, the mixing vessel should be heated by internal combustion of coke or gas, and when the walls of the vessel are sufficiently hot to hold the molten metal without chilling it, it is charged repeatedly from the cars 7 with metal obtained either from a number of furnaces or at different times from a single furnace. The charges of metal introduced at different times into the metal, though differing in quality, mix together, and when the vessel has received a sufficient charge its contents constitute a homogeneous molten mass, whose quality may not be precisely the same as that of any one of its constituent charges, but represent the average quality of all the charges. If desired, the commingling of the contents may be aided by agitation of the vessel on its trunnions, so as to cause the stirring or shaking of its liquid contents. The mixing chamber being deeper at its rear than at the front end, as before described, and its normal position when not discharging metal for the purpose of casting being with the bottom inclined upward toward the front or discharging end, and the bottom of the spout being situate above the bottom of the vessel at its forward end, it is adapted to receive and hold a large quantity of molten metal without its surface rising high enough to enter the discharge spout. * * * The tilting of the vessel does not, however, drain off all the contents thereof, a portion being prevented from escaping by reason of the elevated position of the spout 6, and as the vessel is replenished from time to time each new charge mixes with parts of previous charges remaining in the vessel, by which means any sudden variations in the quality of the metal supplied to the converter is avoided."

Upon these disclosures is based the second claim, which is as follows:

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"In the art of mixing molten metal to secure uniformity of the same in its constituent parts preparatory to further treatment, the process of introducing into a mixing receptacle successive portions of molten metal ununiform in their non-metallic constituents (sulphur, silicon, etc.), removing portions only of the composite molten currents of the receptacle without entirely draining or emptying the same, and successively replenishing the receptacle with fresh ununiform additions, substantially as and for the purposes described."

Stress is laid by respondents on certain other statements in this specification. What their bearings may be in determining the validity or the meaning of the first claim it is neither our duty or purpose to now say. As we construe the second claim, these statements do not apply to the specific process disclosed in the specifica-

tions and embodied in that claim. As we construe that claim it does not apply to the entire art or process of mixing molten metal, but to a mixing process which is "preparatory to further treatment." What that further treatment is is made clear by the specification. It is to "a process of mixing" "before its final refining," and its purpose is to "cause the fluctuations in quality of the successive tappings to be very gradual." It would therefore seem that the metal to be mixed was metal direct from the blast furnace and the further treatment was Bessemerizing in the converter. That this "further treatment" could not be the mere casting in pigs would seem apparent from the fact that a relatively more uniform pig product could be obtained by emptying the vessel and then refilling it than by the continuous method indicated in the claim.

That the Jones process was a radical and important one, that the benefits and profits arising from its use were great, there can be no doubt. The size of the record, the number and character of experts testifying and of the counsel concerned, and the earnestness with which this case has been contested, in themselves, confirm the testimony of its value in the art. But the testimony itself
1000 *51 in that regard is quite convincing. Indeed, we do not understand the respondent's witnesses in effect deny the value of the process; what they allege is that it was not original with Jones, but was well known years before. The regard in which it is held by practical and theoretical minds is shown in the record by a number of witnesses to whom reference has already been made. Mr. Metcalf testifies that, "The Jones mixer has the advantage in the Bessemer practice of equalizing or making more uniform the temperature of the charges from the different blast furnaces, one hot and one cold and one medium, so that the changes in the iron as it goes to the converter are minute, gradual and such as the blower can see and handle without difficulty, so that while he may work from quite a low temperature to a very high one he may still produce good results if the change is gradual, such as he can see from heat to heat. * * * That the clear advantage in the Jones method is this slow and minute change in the character of the metal, as against the sudden change in the blast furnace; this is accomplished by putting successive charges into a large pool of metal and withdrawing it from a different portion of the pool, in such a way that the iron has some time to mingle and make a nearer average mean mixture than it would have if it were taken direct from the furnace to the blower, or if it was simply dumped into a huge vessel in whole taps and drawn out again and the vessel drained and carried off without time being given and care used to produce this averaging up and this slow changing of the composition of the metal."

Mr. Mackey, speaking of the difference between the Jones and the prior practice, says: "There is a great difference between the two. You pour a low silicon into the mixer; then you pour a higher silicon in; that gives you a more uniform iron; where, on the other hand you pour five ladles in small amounts direct from the furnace,

one of those conversions may chill, the other may be so
1000 *52 hot that the blower would be unable to have his temperature regulated properly, and that would also be spoiled by being too hot."

Mr. Kennedy says: "The Jones method has made the direct process, which was attended with great danger and difficulties before the date of his invention, a thoroughly practicable and successful one. Instead of it being a question of great doubt whether to run the metal direct to the converter or remelt it, as it was up to the time of Jones' invention, no one would now think of building a new works, containing both furnaces and converters, without arranging to mix the metal by the Jones method, which not only effects an immense saving in the cost of operating the works, but enables a uniformly good product to be made, and also a purer product that can be obtained from cupola metal, which absorbs and is contaminated by sulphur from the coke which constitutes the fuel of the cupola."

Mr. Sherrard's estimate is as follows:

"I saw the Jones mixer in use at the Edgar Thomson steel works not a very great while after it had been put in, I think in the fall of 1889, and on its operation being explained to me I was struck with the benefits to be derived from getting metal free from the sudden changes in composition and temperature, and this point I appreciated very thoroughly when we commenced to use direct metal from the blast furnaces at Troy without a mixer some two or three years later. The blower or scrapper has to determine how to handle a heat very quickly, and he bases his judgment somewhat upon the heat phenomena connected with the preceding charge of metal. He has means at hand to control quite wide variations in composition and temperature, and can take advantage of these means if only warned in time. It has been my experience that the metal coming from the blast furnace is liable to vary greatly in both composition and temperature from cast to cast, and these variations are so great that the blower or scrapper has little to guide him to
the successful manipulation of the charge. The metal
1000 *53 coming from the Jones mixer, on the other hand, changes comparatively slightly from ladle to ladle, and he can accommodate himself readily to these changes."

Mr. Joseph Massenez, a Belgian engineer, in a leading paper read before the British Iron and Steel Institute of 1891, stated that "this disadvantage of the irregular composition of the individual blast-furnace charges is obviated in a simple and effective manner by W. R. Jones' mixing process. * * * Only a portion of the pig iron placed in the mixer is taken for further treatment of steel, whilst new supplies of pig iron are brought from the blast furnace. In this way homogeneity sufficient for practical purposes is obtained." In discussing this paper at that meeting, the eminent English metallurgical authority, Sir Lowthian Bell, stated that "since they had begun to use the mixer, the defectives from whatever cause, had fallen to something like half of what they had been before. The expense of working the mixer was little or nothing."

It is contended, however, that the Jones process was anticipated by the English patent of Deighton, No. 3672, of 1873, for an improvement in the manufacture of Bessemer steel. The authorities leave no doubt as to the character of the disclosures necessary in a prior patent or publication to avoid a subsequent one, to wit, the information therein given must be so full, clear and precise, that one skilled in the art and acting in the then state of knowledge, can, from such a patent or publication perform the process or make the thing covered by the patent sought to be anticipated. Walker on Patents, No. 57; Curtis on Patents, No. 378; Roberts *vs.* Dickey, 4 Fisher's Patent Cases, 552; Federal Cases, No. 11899; Seymour *vs.* Osborne, 11 Wall., 555; Eames *vs.* Andrews, 122 U. S., 55; Downton *vs.* Yeager Milling Co., 108 U. S., 470; Cawood Patents, 94 U. S., 704. In the light of these requirements let us see whether what is essential and vital in the process was given to the public
1000 *54 by Deighton. In this inquiry the burden is on the respondent, for the grant of the patent is *prima facie* evidence that the patentee was the first inventor of what he described and claimed. Seymour *vs.* Osborne, 11 Wall., 516. In determining a question of this character it is a pertinent and reasonable inquiry, if it be true that the disclosure of an earlier patent was substantially that of Jones, why, during a period of many years, was it not practically applied to the same use? Clark *vs.* Copeland, 2 Fisher's Patent Cases, 221; Fed. Cases No. 2866. And when a great branch of industry recognized the need of just such a process, where that need was a subject of discussion at gatherings interested in practical questions of the art, the inquiry becomes more pertinent and the harder to answer. That no one practiced the alleged anticipation and that no one saw or even suggested such possibilities in it until after the latter discovery was announced are cogent facts which warrant the most convincing assurance to a court that such knowledge was conveyed in a neglected and dormant patent. In his original or provisional specification, Deighton made no reference whatever to the direct process. His device was for use in the cupola or indirect system alone, and is for converter replacement or substitution to secure continuous working of the plant. No mention is made of mixing metal. The mischief complained of was the time lost in repairing converters and the remedy proposed means for quick removal of damaged converters and substitution of fresh ones. It will thus be noted that neither mixing metal or the direct process were the primary or principal objects of the patentee. In the final specifications there is added what is alleged to be the anticipation. This consisted in placing an intermediate vessel between blast furnaces and converters, and into which the metal was run. As carrying forward the originally avowed purpose of the patentee, viz., replacement to secure continuous work, the patentee says of the vessel: "When the vessel in use requires repair, it is replaced by another kept ready for use." It was also arranged on
1000 *55 scales so that the exact amount desired for converter charges could be tapped. On the subject of mixing the disclosures were these:

"Instead of manufacturing Bessemer iron or steel from pig iron which has been melted in cupolas, my invention also consists in taking the molten metal directly from the blast furnace to the converter, in which case I prefer to arrange the Bessemer plant in a line at right angle- to a row of two or more blast furnaces, and place a vessel to receive the molten metal tapped from two or more blast furnaces to get a better average of metal which will be more suitable for making Bessemer steel or metal of uniform quality, the vessel or receiver being placed on a weighing machine so that any required weight may be drawn or tapped from it and charged into the converter."

The mode of operation is thus described:

"y^1, y^2, y^3, y^4, are gates or channels from (for?) the molten metal from each furnace, which channels lead to a receiving vessel 'm,' which is placed low enough to give fall for the molten metal to flow from the blast furnaces to this receiver 'm,' which forms a receptacle for mixing the molten metals from two or more of the smelting furnaces. * * * From the receiver 'm,' the mixed molten metal is tapped and flows down the swivel trough, 'n' into the converter (a). By placing the vessel, 'm' on a weighing machine it can be readily ascertained when the exact quantity required has been tapped from it into the converter. When the vessel in use requires repair it is replaced by another kept ready for use. When from any cause the converters are not at work, the metal from the blast furnaces can be run into pigs, the space (q) on each side of the building for the converters being formed into converter beds."

What disclosures are therein made? In reality, is there anything so far as the present question goes except providing blast furnaces, a converter, an intermediate vessel and troughs leading from the furnaces to the vessel and from the vessel to the converter? Conceding these are the means by which the much-desired mixing can be accomplished, nothing whatever is said as to the method in which these means were used. In so far as the present patent goes there was necessarily nothing novel in the mechanical instruments employed, but the gist and life of Jones' invention was in the process of using the mere mechanical means. On these vital points, without knowledge of which the public would not learn and could not practice the Jones process, the Deighton patent is silent. As to when the tappings are to take place, whether the entire furnace product is to be tapped at once or only a part drawn and like proportions from other furnaces, whether the entire contents of the vessel is to be used in the converter before resort is had to the furnaces for an additional supply or whether this was a mere matter of convenience, depending on the exigency of events; whether a large amount or indeed any amount was retained in the vessel which would approximately average each incoming portion to the retained mass; whether the patentee had found a conjoint process of so adding the molten iron, maintaining a pool and withdrawing the converter charges that a practical graded uniformity of product as well as heat of product could be secured, are points on which no light is given, or, indeed, mention made.

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Conceding, for present purposes, that the patent shows mixing, it must not be overlooked that mixing alone is not sufficient to obtain the results of the Jones process. It was already known that the mixture of different tappings produced a more uniform product, in fact, the cupola system is in substantial form the embodiment of that principle, but other steps must be added, and it is on these steps, on which the Deighton patent is simply silent, that Jones built and made a success of the direct Bessemer process. When the necessity for disclosure is absolute, silence is fatal.

It is true witnesses, testifying in the light of subsequent disclosures, now say they find in the Deighton patent the
1000 *57 substance of Jones'. If Deighton saw as much; if he had a full, clear and precise knowledge of Jones' process,—and he must have such knowledge to have disclosed it in his patent—it is a singular fact that no one discovered what he meant until after the Jones process was in successful operation. Searching thoroughly through the literature of the art in the record, we find no trace of Deighton's patent as a factor therein. The patent itself seems to have been allowed to lapse in a few years, and when it thus became open to free use, the art, judging from its acts, saw nothing to adopt in it, and the statement of Mr. Snelus at the British Iron and Steel Institute of 1878 (see Journal introduced by respondents. Record, vol. 3, page 1104), was "that no one in England as far as he knew, was using any intermediate receiver between the blast furnace and the converter."

To our mind, the true place of this Deighton patent in the art is in the line of the Holley receiving ladle. Like that appliance it afforded a means for storage and weighing. But being capable of tipping and pouring charges, the Holley ladle was an advance on it. In both the primary objects were storage and weighing. That some mixing was incident to the practice is true, for mixing is a recognized operation of nature where two or more quantities of fluid are run together, but, as we have said, mixing ending with mere mixing is not the Jones process. Its gist is using that mixture as a dominant, intermediate pool to tone or transform eccentric incoming charges into approximately regular, graduated, outgoing ones. Thus it will be seen that while Deighton's patent was a possible step forward, he wholly failed to reach, much more disclose, the vital point of the Jones process.

It is contended, however, that the respondents have secured satisfactory results, practically those obtained by the Jones process, from an experimental plant constructed in accordance with the instructions of Deighton's patent. This plant was constructed
1000 *58 after suit was brought, and no opportunity given complainants to inspect the same or to witness its operation. Waiving for the present the objection promptly made to evidence concerning such plant and its operation, we are by no means satisfied that the means used were a reproduction of Deighton's or the process employed was not the identical one of Jones. It is clear that to be illustrative and reliable an experimental plant should be a substantial reproduction. Here we have a departure. Deighton

uses troughs from the furnace to the vessel while the reproduced plant uses ladles. On respondent's side it is testified that this was a matter of no moment; on the other side it is testified quite positively, and we find no contradiction in that regard, that the iron coming down a runner from a blast furnace carries with it a large amount of sand, which chills very rapidly.

So also in regard to the cover used on the receiver. There is no warrant for it whatever in Deighton. As to its importance there is conflicting testimony. Respondents claim it was a matter of indifference. If so, it, as well as the ladle noted above, should have been omitted. But under the proofs, we cannot agree with respondent's contention. Indeed, the absence of all reference to a cover in Deighton and the placing of one on the experimental plant are suggestive. The cover seems to be a feature of a mixing vessel essential to the successful maintenance and working of a dominant pool; it was used in the experimental plant; it was not mentioned in the Deighton patent. Conceding the competency of the evidence (upon which we express no opinion), by reason of the variations noted we do not regard the experiment as fairly illustrative.

The patents of Witherow, No. 315,527, and No. 327,425 both granted in 1885, are cited as anticipations. Turning to the earlier, we find not a process, but an apparatus, patent. The patentee's avowed purpose was "to facilitate and cheapen the conversion of crude cast iron into ingot iron or steel by the Bessemer
1000 *59 or pneumatic process." The suggested means were utilization for converting purposes of the blast forcing and heating apparatus of the furnace. This he does by placing a blast connection between the Whitwell stove and the converter. Of the economic and metallurgic advantages resulting from his device, he says:

"My invention is applicable without change and with great economy to existing blast-furnace plants. Such an application utilizes the blowing engines and blast-heating stoves of the plant, and consequently saves the expense of constructing separate ones for the converter, and at the same time does not interfere with usual and ordinary operation of the blast furnace. It also saves the cost of a cupola for melting the metal to be charged into the converter, for it brings the latter near to the blast furnace, so that it can be charged directly therefrom."

A study of the patent shows to the candid mind that this was all Mr. Witherow believed himself to have invented and all he disclosed to the public. That the use of an intermediate storage receptacle was a mere incidental, mechanical, temporary expedient and that storage, and not uniformity of even individual fillings, much less continuous gradual changing uniformity of product was its function or purpose is clear from the specification. Thus he says, "Extending from the blast furnace to the charging hole of the converter is a charging spout of the usual construction. This spout enables the converter to be charged from time to time directly from the blast furnace." This clearly shows that the avowed object of the invention could be carried out and was intended to be ordinarily

carried out directly from blast furnace to converter. The advantage gained lay wholly in the patentee's judgment in the use of the furnace hot blast in the converter. Thus he says:

"The use of the hot or superheated blast is of great advantage in case the molten metal in the converter becomes too cold for its proper treatment therein, as in case scrap is charged, or
1000 *60 the heat-producing elements are exhausted, or nearly so, for the heat imported by the blast so increases its *califoric* power as to enable it to restore the metal to its proper condition of fluidity. Thus much of the danger of the metal's chilling in the converter is taken away. It also augments and intensifies the reactions in the converter, shortening the blow, and aids in the dissociation of the impurities, which may be tapped off during the blow."

He has added to the system an intermediate storage vessel because "it is often undesirable to tap the metal from the blast furnace every time the converter, which is relatively much smaller than the blast furnace, is charged." It was preferably constructed to take the whole amount of a cast, but might be made for a smaller quantity. The vessel was mounted on a hydraulic piston placed in a firebrick pit and was raised therefrom and its contents tapped into converters, "of which there may be several," or it could be dropped below the floor surface and the pit closed by a suitable cover. By this means the patentee proposed to maintain the heat of the metal, so as to keep it as long as necessary in the proper molten condition for tapping off into converters, "of which there may be several." It will thus be seen that the purpose of this vessel was storage, and storage alone. There is no reference whatever to the subject of mixing. That the means used by Witherow might be employed in the Jones process is not to anticipate Jones' patent if he was the first to suggest such a use. That storage and storage alone was in view by Witherow is also shown by the fact that he suggests its use in the cupola or indirect process, where its desirability for storage is manifest, but for mixing comparatively needless. In the second patent we find an advance in the same general lines as in the preceding, viz., in storage. The obstacle to be overcome is stated by Witherow in these words: "The difficulty of using the molten metal from the furnace in the converter consists in keeping the large quantity of metal from the latter in a proper condition for use in the furnace. The
1000 *61 time between charges of the converter is usually twenty minutes and upwards, and the metal from the furnace must be kept in condition to be tapped from time to time as needed. This is the object of my invention." To this end he provides a vessel, styled a "receptacle," of sufficient size to hold the entire cast of the furnace, provided with a cover and tuyeres to blow down on the surface of the metal. This blast agitated the bath and caused the formation of a slag surface, which promoted excessive oxidation and loss of heat by radiation. Such is the entire disclosure of the patent. It is storage and heat conservation alone. No mention of mixing whatever, is made, or are the evils of non-uniformity of the furnace product recognized. The purpose, object and means of the

two patents are wholly in a different direction. It is significant in both that neither of the terms used, viz., "distributing receptacle" and "storage receptacle," suggest the design of mixing, while the mention throughout of but a single blast furnace in both, (so frequently recurring as to be of marked significance) and the use of several converters with such single furnace would indicate that a speedy emptying of the vessel was the process in the patentee's mind. If he had any conception of the Jones process in view, he was happy in veiling it. To see in these patents a number of furnaces and but a single converter instead of the several specified, and that the process involved the tapping of such imaginary furnaces into the vessel, and the use of but a single converter to deplete it and the consequent maintenance of the Jones dominating pool conveys some notion of the distortion demanded to find the Jones process in the Witherow patents.

Considered as an anticipation of the English patent of 1856 to Tabberner, No. 2061, deserves but brief reference. So far as pertinent to the question in hand, it teaches the use of a number of small furnaces instead of one large one and from which frequent tappings are made "into one large reservoir from which the molten metal may be drawn for casting from." Although the patentee makes no reference whatever to mixing and to the advantages to be gained therefrom, so that there is no disclosure on that point, yet conceding, as respondent's expert claims, "that Tabberner understood fully the art of mixing metals from a number of smelting furnaces in one large reservoir, from which the molten metal may be drawn for use as required," (a general principle, as we may say, which had been recognized for years before) yet on the subject of maintaining and using the contents of the molten pool as a dominant and unerring agent for receiving non-uniform products and delivering an approximately uniform one, in other words, on the gist of the Jones process, Tabberner is silent. The fact that this patent practically antedated the Bessemer process, and the difficulties which the direct use of that process disclosed so many years, is itself suggestive that it does not anticipate.

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The discussion of these patents and the reasons which satisfy the court that they do not anticipate the Jones process renders needless a discussion of the many others cited as anticipations.

It is alleged, however, that the Jones process was disclosed by Mr. Snelus in discussions reported in the Journal of the British Iron and Steel Institute. Such a contention is in our judgment based solely on selecting excerpts of what he said, removing them from their surroundings and reading them as though they were connected and delivered together. Read as they were reported and in the light of their surroundings, they do not disclose the Jones process. Mr. Snelus' views in the report of 1874 were in substance these. He advocated the use of the direct process; the trouble he discussed therein was variation in silicon; that there was no great difficulty in this after they got the furnace working properly, the metal could be analyzed, and too silicious, could be toned by

adding non-silicious cold pig. To facilitate this, as we gather, he urged running the metal into an American inter-
1000 *63 mediate ladle and "they could then deal with it as they liked." This intermediate ladle was advocated as a means for aiding in treatment, and no reference was made to mixing in general or the Jones process of continuous maintenance of a dominating pool. That his notion of the function of a vessel was as a storing vessel, and not as a mixing one, is emphasized by his statement, so late as 1878, in the discussion reported in the journal of that year that "The great drawback to the direct-casting process was, that you could not always get your metal at the exact time you wanted it. He believed it would be found that the great advantage the Bessemer works in America had was the intermediate receiving ladle, etc., which was designed by Mr. Holley and which was universally used there, although it was never used in England." It is true, he adds, that he thought the ladle was important "both for saving time and for facilitating the admixture of iron," and that thereby you could hold it in readiness, so that at a moment's notice you could take your iron into the converter and also obtain a better mixture. But this bare idea, and that is all it was, cannot under the decision noted be regarded as a disclosure of the Jones process of the use of a dominant pool to produce a relatively uniform product from non-uniform constituents. Against objection respondents introduced the record of the institute of 1891, subsequent to the patent—and allege that Mr. Snelus therein claimed that twelve years before he had disclosed the mixer process. Waiving for present purposes the question of the competency of the evidence, we cannot agree with the conclusion drawn therefrom by respondent. At that meeting Mr. Massanez had, in the paper under discussion, and to which reference has been made above, given credit by name to the Jones mixing process, as having in a simple and effective manner done away with the disadvantage of the irregular composition of blast-furnace charges; Mr. George Lauder had given the mixer great credit for "the magnificent blast-furnace practice brought before the institute at its meeting in New York, by Mr.
1000 *64 Gayley," and Sir Lowthian Bell stated that "Since they had begun to use the mixer the 'defectives,' from whatever cause, had fallen to something like one-half of what they were before." Mr. Snelus' remarks were brief and near the close of the discussion. In them he made no claim that the Jones process was his or that he had disclosed it. Far from it; he said he had seen the mixer Sir Lowthian Bell had spoken of and bore testimony to the accuracy of his statements; he said that twelve years ago he made part of an apparatus for a large mixer, but he was stopped before completing it. What the mixer or the process he proposed were, he did not state. He further said he had many talks about the success of the operation with the late Mr. Holley, who assured him that there could be no difficulty in it—"He was now pleased to find that these ideas had borne fruit." These statements by Mr. Snellus cannot, in our judgment, be regarded as a claim by him of

an invention which had been expressly attributed at the beginning of the discussion to Jones, which had not been questioned by one of the speakers; which was certainly not denied by Mr. Snelus. In summing up his connection with the process, we find nothing but an account of a partly finished and abandoned construction of twelve years before, and conversations with Mr. Holley, who expressed his belief in the solution of the question. To construe these remarks into a disclosure of the Jones process would, in our judgment, be to award Mr. Snelus, what he never claimed; much more, never taught the public.

From the literature anticipations of this process let us turn to alleged anticipations by way of actual use. We discuss in detail but two. The cupola ladle and the Whitney car-wheel practice, they being fairly representative and bearing the seemingly closest relation to the Jones process. Failing to find anticipations in them, discussion of other uses, further removed, is needless. In searching whether a practice anticipates, it is fitting, to
1000 *65 ascertain and recognize clearly what object was in view in such use. Thereby we are the better able to ascribe just and exact significance to the means used to secure such end. Now, while there are variations and non-uniformity in the product of cupolas in the Bessemer cupola practice, and while the workings and product of such cupolas are at times non-uniform and divergent, yet the general fact remains that the product is so substantially homogeneous that the metal for converter use can be taken direct from the cupolas and used with commercial success. This fact is shown by the continued and successful practice of the cupola process in England for years before the use of an intermediate ladle was known. This is shown by the testimony of Mr. Forsyth, a well-known theoretical and practical metallurgist, called by respondents, who says that in the exclusive use of cupola metal in Bessemer practice, the degree of non-uniformity of the metal was not such as to make a mixer necessary. Whether such results were obtained through the comparative thoroughness of pig selection, or whether the cupola itself served as a mixer, the fact remains that good commercial results were obtained from its product. These facts have been clearly set forth by respondent's witness, Mr. Hunt, who says, "In most cupola practice a great variety of metals are used, varying greatly in both their physical and chemical characters, and it is often the case that through such mixture in the cupola that metal is utilized which could not have been used at all if taken direct from the blast furnace. That is, should the blast furnace have been working so badly that the produced iron was unfit for the Bessemer practice, it would be homeopathically mixed with better material in the cupola, which after melting would be averaged up in the accumulating cupola ladle and thus ultimately make good steel." There was, therefore, no crying need in that practice for a radical change in the line of greater uniformity. While greater uniformity was desirable it was not an indispensable requisite.
1000 *66 But the needs and lacking elements of the process were two, storage and weighing of charges. Out of these

needs grew the Holley intermediate ladle. These were the causes, object and functions which respectively created it and functionally used it.

That the foregoing statements and conclusions are based on facts will appear from the proofs. Prior to the introduction of the Holley ladle, the tapping from an individual cupola was not sufficient for a converter charge. Moreover, a stinted supply of metal from the cupola left the converter department idle, and delay or derangement in the converter department necessitated running the cupola metal into pigs. These needs suggested the use of a balancing, intermediate factor and found expression in the Holley ladle. By means thereof, metal drawn from one cupola, in itself insufficient for a converter charge, could be held until another cupola supplied the needed amount, and, on the other hand, if there was delay in the converter department in using the metal, it could be held there until needed. The purpose was storage, and the ladles were functually used for that purpose. If the production exceeded converter capacity, there was storage of more metal; if the converter capacity exceeded the supply, there was less or even no storage. It will thus be seen that the quantity of metal in the ladle was dependent on the relative workings of converter and cupola. It was also modified by the practice of weighing. To insure full converter charges, weighing was adopted. It was made possible by the ladle, and as short weight was objectionable and resulted in short heats and poor product, the keeping of an overweight in the ladle occurred. Now that mixing of some character took place in the ladle during these operations, that where it took place the resultant was a homogeneous average of all constituent ingredients contained, are facts to gainsay which would be to question nature's laws; but the indisputable fact remains that such mixing was accidental, eccentric and non-systematic, and therefore not of a systematic, regular, functional type or for a systematic, functional purpose. That storage and weighing, mere mechanical processes, were the ladle functions recognized and valued in the mind of the steelmaker, is shown by the literature of those years. In the transactions of the American Institute of Mining Engineers for the centennial year, is an able and exhaustive paper on Bessemer manufacture in America, by Mr. Robert W. Hunt, one of the foremost representatives of metallurgy in this country. In summing up the art, Mr. Hunt attributed a large part of its advance to Mr. Holley, gives the ladle great credit, and contains this highly significant statement, which, coupled with the entire absence of reference to mixing becomes even more significant. He says: "The result of his thought gave us the present accepted type of American Bessemer plant. * * * He substituted cupolas for reverberatory furnaces, and last, but by no means least, introduced the intermediate or accumulating ladle, which is placed on scales, and thus insures accuracy of operation by rendering possible the weight of each charge of melting iron, before placing it into the converter." Mr.

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Holley himself (see article on Bessemer machinery in London Engineering, 1873) describes the function of his ladle in these words:

"Interposing ladles between the cupolas and vessels, is important in many respects. 1st. The cupola cannot be so economically and regularly worked if its hearth has to fill up with the whole 12,000-pound charge of iron every hour. 2nd. The weight of the charges should be somewhat uniform to promote uniformity of the accuracy of blowing, and to recarburize with a fixed percentage of spiegeleisen. This can only be accomplished by weighing the charge between the cupola and the vessel; and the ladles are placed on scales for this purpose. 3rd. Several charges are often run into the ladles when the converting department is not ready for them; otherwise the cupola would have to be dumped, and part of a day's work lost."

1000 *68 Four years later (see article—An analysis of the American Bessemer plant, in London Engineering, 1877) he also describes the purpose of the ladle, thus:

"The cupola ladles facilitate the distribution of metal to the vessels. They form reservoirs which make the melting department and the converting department independent of each other, within limits. This advantage was not fully appreciated until the large productions of the last two years were attempted. Should any delay occur in casting, in preparing a vessel, or from any cause, the melting department keeps right on, for these three ladles will hold six vessel charges, which may be stored and converted when the converting department is ready for them. Cast iron will 'live' in these thickly lined ladles, when covered with charcoal, for several hours. But it is necessary to put these ladles on weighing machines, so that either uniform vessel charges may be run out, or so that the spiegeleisen may be proportioned to such charges as are run out."

Now it is highly significant that in neither of these descriptions does Mr. Holley, who certainly knew better than others the functional purposes for which his ladle was intended, intimate that it was to perform functions analagous to those of the Jones mixer. Avowedly, it was arranged to enable the iron to be weighed and also to give a reserve storage capacity, but there was no mention of carrying a constant body of iron therein for the purpose of promoting uniformity between successive charges.

That storage and weighing were the marked function of the accumulating ladle is evidenced by the practice of the respondent company. In 1871 it installed a 21,000-lb. ladle, when its converter charges were 12,500 pounds. In 1877 it increased this ladle to 28,000, the converter to 15,500; in 1889 the ladle to 32 to 35,000, the converter to 26,000 to 28,000; in other words, in 1877 the capacity of the accumulating ladle above a converter charge was 3,500 lbs., in 1877, 12,500, in 1889, 7,000 lbs. It will

1000 *69 thus be seen that the outgrowth of 18 years' experience with the accumulating ladle had led not to an increase but to a marked decrease of its functions to form a dominant, governing pool. In 1871 the capacity of the ladle in excess of con-

verter charge was 3,500 lbs. Assuming that amount was left in the ladle, and that 12,500 lbs. were then added, the proportion of the residue or dominating pool to the incoming metal was as about 8 to 12. In the latest development of the ladle the residue had dropped to 7,000 lbs., while the incoming metal had raised to 28,000 lbs., so that the proportion of the dominating pool to the incoming metal had changed from 3 and 2 to 1 and 4. The significance of these figures requires no comment. The fact is that a moderate proportion seems to have been left in the ladle to insure continuous working and proper weighing, and that the ladle was proportioned accordingly. That an intermediate storage vessel was more imperatively called for in cupola practice is well set forth by Mr. Hunt, who says:

"Again a great advantage of such a reservoir is making the various departments of the establishment, to a certain degree, independent of each other. If you do not have such a reservoir in the cupola practice and delays occur in the converting works, it would necessitate taking the blast off of the cupolas, and should such delay extend over a considerable period of time, the melted metal in the hearth of the cupola would either chill up and render it necessary to drop the bottom of the furnace, or else it would have to be tapped off in some convenient manner, and thus become awkward to handle as scrap. On the other hand, when running on direct metal, should delays occur at the converting works, the metal from the blast furnace can be cast into pigs of commercial and uniform size and shape which could be subsequently melted in cupolas or used for other purposes, and thus the regular working of the blast furnace not be disturbed."

1000 *70 While mixing in an accumulating ladle might take place, the proofs show that whether it did take place was wholly a matter of working conditions and not of design. Mr. Hunt, called by respondents, says, in reference to the Cambria practice, "Whether or not the metal was left after pouring the charge, depended upon the relative speed which the cupola was melting, and the metal being converted in the converters. If the blowing was close up to the melting, the metal would be poured as soon as sufficient amount for a heat was accumulated. If, on the contrary, the melting was ahead or faster than the converter, there would be frequently a large proportion of another heat retained in the ladle after pouring, and into which more metal would be tapped from the cupola."

It would thus seem that no effort was made to secure the possible advantage of mixing at the respondent's works, and Mr. Fry, a witness for complainant, who was superintendent for ten years of this practice, testifies most positively, and I find no direct contradiction of his testimony by Mr. Hunt, who was in general charge of the Cambria plant, that there was no recognition at that time by Mr. Holley or Mr. Hunt, by himself or by any other person, of any mixing operation by the cupola ladle, such as is secured by a dominant pool. Golding, for six years superintendent of the Pennsylvania Steel Company, says that under the charging practice at

Steelton no such mixing occurred, that the vessel was generally drained at each charge, and that "The object of using the ladle for the purpose of a mixer was not once thought of by me, nor by any one, as far as I know." Mr. John S. Kennedy, superintendent of the blast furnaces of the Pennsylvania Steel Company from 1881 to 1887, testifies substantially to the same effect. He says, "I never knew of the ladle being used for mixing purposes. If such was the practice I would have known of it. * * * The capacity of the ladle was so small and the size of the pool of metal, when there was a pool, was of such varying size, that I do not see how any mixing could be accomplished. * * * The ladle was often drained."

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In line with what we have said in regard to making the relative size of the ladle less at the Cambria iron works and thus negativing the contention that its mixing function was fully recognized, it is here to be noted that in the Pennsylvania Steel Company practice their ladle was reduced in size from fifteen to ten tons. Moreover, that the function of the ladle in the cupola system was not mixing, is shown by the fact that in the light of disclosures of late years of the great benefits accruing in the direct system from mixing, the Jones & Laughlin cupola plant, a progressive firm, of this city, continue, as testified in this case, to use ladles between the cupola and converter, which only contain a single converter charge and with them produce a uniformly high grade of metal.

We next turn to the Whitney car-wheel practice, which is alleged to anticipate the Jones invention. This particular use dates back almost fifty years and is fairly representative of ordinary, well-known foundry practices. The same general method was in use in foundries connected with Bessemer plants. The inquiry, therefore, reasonably and properly arises, if the analogy and adaptability of this practice were so apparent, why were they not recognized and the practice used to remedy the long-felt and well-recognized evils of the Bessemer direct process? That they were not so recognized affords substantial grounds for questioning their alleged analogy and adaptability (in and of themselves and without the aid of other elements involving invention) in that regard. That this foundry practice was well known, that its general features were practiced in close proximity to and in common with steel-making, that it concerned a large and well known branch of industry, that no such analogy and adaptability as are now contended for, were discovered and practically applied through a long period of urgent calls for relief, are facts which should lead a court to carefully scrutinize the opinions of those who now say that such practice afforded and suggested to the mind of those skilled in the art the means of relief which all wanted but none saw.

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We must avoid being misled by mere terms and subjects of work. While Jones and Whitney both concerned the melting of metals, yet they had widely different objects in view. Whitney's purpose was to cast molten metal into a finished product, Jones' merely to prepare molten metal for further treatment, to wit, decarburizing it

into steel. The *sine qua non* of purpose in Whitney was product uniformity. Uniformity of quality in car wheels is required, so they will stand wear and uniform wear.

In the Bessemer direct process you cannot secure, initially or by treatment, uniformity of molten metal; so far as yet developed, the best you can do is to make the non-uniformity gradual and not abrupt; in Whitney, non-uniformity whether gradual or abrupt would be alike fatal. In Whitney, relatively absolute uniformity is an essential of product and a sequence of material used; in Jones, uniformity is a non-essential, in fact a non-attainable attribute of product, and is a necessary non-sequence of material used. In Whitney, we remelt in a cupola metal which has already undergone the refining process of the blast furnaces; in Jones, we take metal direct from the furnace and discard the cupola. It will thus be seen that apart from the wide difference between the primary work of a huge blast furnace, the base of all metallurgy, and the cupola of the founder, a mere subdivision of that art, we find in the Jones and Whitney processes a substantial difference of purpose, of process and of subject-matter of work.

The vital necessity of a constant, unvarying uniformity in car-wheel product is apparent from the liability to accident resulting from its absence. Without entering into a detailed statement, it is sufficient to note that the faces of the car-wheel flanges must be chilled to stand wear. Chilling is at the expense of ten
1000 *73 sile capacity, hence the unchilled iron back of the flange must afford the tensile strength required in the wheel. The chilled flange, therefore, must be of sufficient, but not more than sufficient, depth To successfully secure enough, and yet not too much, exterior chill, molten metal of uniform character is necessary. But, in addition to the uniform character of the metal in a single wheel, each wheel must in itself be uniform with its companion wheels, so as to stand the same strain. Respondent's counsel quote with approval the testimony of complainant's witness, Mr. James Gayley, to the effect that "it is necessary that each wheel should be like the others, not only made during the same day, but the same throughout the month and throughout the year. This is very important, as the car-wheel maker who risks a change in the composition of the wheels risks his reputation and his trade." We start then in the Whitney process with the end in view of attaining and maintaining an unbroken dead line of uniformity. Now, to do this, we initially use chosen grades of metal, which it is to be noted have already undergone the refining process of the blast furnace. Mr. Whitney testifies that a great variety of metals are used; some of high chilling quality; some of low pig metal and broken car wheels, which it is to be noted had undergone several stages of refining process. "We never introduced iron," he says, "into the mixture without first testing that iron by itself, the great variety of tests to ascertain its special individual character. Having ascertained that for each iron that we used in the mixture we mixed them in the proportion which our experience dictated, so as to produce the best results. That was the first step towards securing

uniformity; that is, I mean by mixing them we regulated the proportion and amount of each iron to be used in the mixture; that is, we would have 100 pounds of this iron, 200 pounds of that iron; 300 of another, and so on; that was determined in the office. We formed that mixture of iron from our experiments. Then that mixture was weighed in draughts of about 2,000 pounds each, each draught consisting of its proper proportions of these several different irons, as I have named—100 pounds of one, 200 of another, etc. Then those draughts were charged into the cupola upon a bed of coke between each draught of iron until the cupola was full, when the blast was put on as this iron melted. I may say, in passing, that it was charged when we were running full heats in three cupolas especially set apart for melting wheels. As it melted in these three cupolas, a spout leading from each cupola conducted it into the large ladle which stood in front of them. That ladle held from 12 to 15 tons of molten iron, according to the way in which it was lined up with firebrick. When the ladle was nearly full we began to pour from it into the smaller ladles, each one of which held enough for one wheel; if it was an ordinary-sized wheel it would hold enough for one wheel and if the wheels were smaller ones it held enough for two or three. As that drew the molten iron from the ladle, and the iron continued to melt, the ladle was constantly being filled from the cupola and it was kept full until all the iron charged into the three cupolas was melted and the bottoms dropped. Then the iron was continued to be poured out of the large ladle until it was all used, those two methods making the uniform mixture; that is, we mixed it in a solid state, first by our charges and then in the molted state in the large ladle. * * * As the mixture was charged into each cupola, as I have stated, it was made up of irons from various furnaces, some iron having one quality and some another. As it is melted in each cupola, it did not all melt at the same time, and if we had drawn it directly from the cupola into the small ladle from which we poured the wheels one wheel might have been poured out of very hard iron, another out of very soft iron, and so every shade between. There would have been no uniformity in our work. But by taking it from the three cupolas, all melting the same charges of iron, and collecting them in a molten state, the inequalities of melting were all overcome and a uniform product produced. * * * They were generally tapped very simultaneously. The iron melted very uniformly as a rule in each cupola, so that once iron enough for a wheel was melted in each cupola it was drawn out into a ladle. There were generally enough for three wheels drawn at a time into the large ladle; about a wheel would melt in each cupola, and the three cupolas were tapped about the same time."

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Now, from these facts it would seem, first, the process was so adjusted that a filled reservoir contained the character of iron desired; and second, that the care in selection of material was such that no incoming charge was of a character sufficiently variant to change the uniformity of the reservoir contents. This last fact is highly

significant and illustrates the extent and marks the limitation of the process. That it went further than this is not proven, and that it illustrated more cannot be contended, for if the primary selection was such that any tapping was of so variant and eccentric a character as to change the level of uniformity of the homogeneous product once obtained in a filled reservoir, then the reservoir's contents was not fitted for car-wheel casting. That mixing took place may be conceded, but it was a mixing of constituents which could only and must eventually result in unvarying uniformity. To that extent we may concede it taught mixing, but there its teachings ended, and that was just where the need of the direct process began. When it came to treating a succession of tappings so marked and eccentric as to change the average of the intermediate vessel's contents and result in the outgoing of a non-uniform varying product. Whitney taught nothing, for in his practice the possibility of such a condition was obviated by the preparatory painstaking choice of material. In considering Whitney's teachings to kindred arts, it must not be forgotten that fairly considered storage was the principal object of his reservoir, and mixing the mere incident. That storage was the prime necessity will appear from the fact that foundry casting was a congested process, restricted to a few hours of the day, and applied to a number of relatively small objects, and each flask filled by hand pouring. During such hours it was continuous, rapid, and the only work done. Filling in succession at a cupola tap single ladles of a capacity for a single car wheel would have been intolerable, even if practicable, as business expanded. As cupolas and flasks increased in number an intermediate storage reservoir became a necessity. It would therefore seem that the substantial teaching of the foundry practice was storage rather than mixing. The minute, painstaking, preliminary, selection of material in car-wheel practice showed that the substantial mixing, the mixing essential to success, was done by the founder, ("that was determined in the office," Mr. Whitney says,) before the metal was put into the cupola, and not after it came out. It would seem, therefore, that the foundry reservoir would be regarded by workers in kindred arts more as a storage than as a mixing receptacle. Whatever grounds there are for contending that its teachings were such as to point the cupola Bessemer worker to the use of an intermediate reservoir, certainly it did not inform the direct Bessemer process worker how to avoid his difficulties. The problems confronting Whitney and Jones were not the same, as we have seen; the subjects of work and the objects in view were different.

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That a dead level of uniformity of blast-furnace product would have obviated the evils of the direct system goes without saying. But the crude, unrefined character of the ore, the variant, eccentric character of furnace working, and other factors made, and even now make, such uniformity a simple impossibility. The uniformity reached in Whitney's practice was therefore no solution of the treatment of non-uniformity of blast-furnace product. The question facing Jones was not how to reach uniformity, but how to obtain a

gradual non-abrupt non-uniformity. Conceding that
1000 *77 Whitney may have taught Jones (what is in fact a simple law of nature) that by intermingling different constituent elements you secure an averaged whole, yet there he stopped, for when the blast-furnace men had that mixture, the mixture of Deighton, of Witherow and others, his difficulty was still unsolved. Nor did it teach him what the Whitney process did not involve, namely, the process of using that mixture as a governor or a dominant pool, by which he could treat charges of a character so radical as would avail to vary the entire pool, and obtain from such, a graduated, non-abrupt product. Now, while it may be urged that this change was a simple one, yet it occurred to no one. In the light of accomplishment, changes may seem simple but what is seemingly simple in the brightness of solution may have been very obscure and hard to discover as an original conception. At any rate, in this step, simple or abstruse was the future of the direct process. Its principle, too, was so novel, and the application of it so original, that even after Jones announced it, experienced steel men failed to grasp its significance. This is conceded by such persons. Mr. Gayley, the superintendent of the Bessemer department of the Edgar Thomson works, says:

"I remember very clearly the occasion of first filling the Jones mixer at the Edgar Thomson works. Without any conference with Capt. Jones, the inventor, we had concluded at the furnace department that the way it would be operated would be to fill the mixer up, drain it out entirely and then fill it up again; and, as a mere matter of fact, after being filled, we stopped casting, and I gave orders to draw no more metal until the mixer was nearly empty, and just long enough before so that we could charge it a second time as rapidly as possible. I recall that, standing alongside of the mixer with Capt. Jones, when two or three heats were withdrawn, he asked me why there were no filled ladles there to keep the mixer
full. I replied that I supposed the mixer would be
1000 *78 drained before recharging, and that I had not given any orders for metal to be supplied. Capt. Jones replied, that his intention was to keep the mixer always full, and to issue orders to that effect * * * As this was at variance with what I had conceived as the method of operation, it impressed itself very clearly upon my memory."

Mr. Lauder, of the complainant company, says:

"The question of adopting the mixer was brought up frequently before it was decided to experiment. I recollect distinctly that I opposed it strenuously. I asked if any man had done it before, not only Capt. Jones, but from almost anybody that I thought I could get information from. The answers were uniformly in the negative. For this reason I kept up my opposition to the experiment on the ground that it was too much of an experiment altogether for us manufacturers to meddle with. It was only after continued and urgent representations that I acquiesced in the experiments we made."

Mr. P. T. Berg, mechanical engineer at the complainant's works,

says: "The general expression of opinion at the Edgar Thomson works were that the mixer would be a failure; that it would be impossible to keep the metal liquid and that the metal would scull badly." Mr. Thomas James, master mechanic, says Jones told him he was going to build a mixer to hold a hundred tons, and witness told him he would have a crane that would lift that amount, "that it would only be a question of time until it would chill up solid."

That the operation of the mixer was novel and experimental in the eyes of Bessemer manufacturers is shown by the fact that they wanted to see what its results would be. Mr. L. Robert Forsyth, then chief engineer of the Illinois Steel Company, who was called by respondent, says: "Some years elapsed after the installation of the mixer at the Edgar Thomson works of the complainant, before another mixer was put up at any other works. * * * I believe the mixer is now in at four works beside those of com-
1000 *79 plainant. * * * Undoubtedly, the manufacturers were waiting to see how the process would result and what difficulties arose in operating the mixer."

Another fact should not be overlooked which shows the inherent limitations of the Whitney practice and the extent of its teaching. If it taught mixing, it stopped there, and did not teach the continued maintenance of the pool as a means of securing a graded product, which is the essence of the Jones process. This is shown by the fact that except for mere mechanical operative convenience, there was no purpose in the Whitney practice is maintaining a pool. In Whitney, the reservoir once filled produced the uniformity desired, and uniformity of product was secured, even if the contents were wholly withdrawn. In fact, such was the invariable practice after the cupolas had melted their contents. This was, for aught that appears, the practice in Deighton and Witherow, but this was not the Jones process. The heat condition, absolutely necessary in the steel-maker's art, for heat is the base of that art, presented a different problem, and it was found that unless the fresh-supply metal was constantly added to the pool the variant heat conditions so fatal to successful conversion began to appear, and resulted in enforced resort, as the latter part of the metal was reached, to the wasteful practice of side-blowing. Moreover, it is to be noticed that while all the purpose of Whitney could be secured by filling and then entirely emptying the reservoir, to wit, a uniform product; the effect of Jones, to wit, a non-abrupt change of product, could not be secured, for the contents of one reservoir would be no index of the character of its successor.

It is also to be noted that the substance of this practice is found in Kirk's Treatise on the Founding of Metals, in an account of the Wheeling foundry practice, as follows: "A quantity of molten iron should be kept in the cupola or in a large ladle, so as to give the different brands of iron a chance to mix. In most all
1000 *80 the foundries at Wheeling, West Virginia, the cupolas are never stopped from the time the blast is put on until the bottom is dropped. A large ladle is set on trestles in front of the cupola, in such a manner that the iron can run into it from the

cupola and be poured out into the smaller ladles at the same time. The iron is all run out of the cupola as fast as it is melted and is mixed in the large ladle. I think this is a good way of mixing iron." This volume was cited in anticipation on the application. The subsequent issue of the patent evidences the judgment of that office that it did not constitute an anticipation.

But conceding for present purposes that what there was of Whitney's practice was embodied in Jones' process, does that certainly prove it an anticipation? We think not. The purpose of Whitney was, as we have seen, relatively absolute uniformity of product. That result was never attained by Jones or any one else in the direct process. His object was graduated, non-abrupt change. Jones' object was not, and from basic conditions could not be, produced in Whitney's practice. Therefore, the objects were different. Such being the case, the use of Whitney's entire process in co-operation with other elements or change of process or method to accomplish the novel result which Jones produced, can in no sense be termed a double use. It would be the use of an old method, conjointly with other elements, to produce a different and new result. The old element may remain unchanged, but the action of other elements co-operates with it conjointly on the common object and produces a new result. The new process, to wit, the Jones process, is applied to a different object, and a new result, viz., graduated, non-abrupt converter charges, result from such application. It therefore comes within the spirit of Whitney *vs.* Mowry, 2 Bond, 45, Fed. Cases, No. 17592, and Cary *vs.* Wolf, 24 F. R., 139, and kindred authorities. In Mowry *vs.* Whitney, 4 Wallace, 640, a case, by the way, involving the wheel practice of Whitney, is found in Mr. Justice Strong's opinion what we regard as the underlying
1000 *81 principle which differentiates the Whitney practice from the Jones invention. The question in issue being a peculiar kind of annealing, and the subject of discussion, prior practices, it was said:

"It is unnecessary, however, to describe these devices. It does not appear that in any of them the idea existed of making a car wheel with chilled tread, straight plates, and solid hub, annealed and cooled so as to leave it uninjured by the strain attendant upon the unequal cooling of the thick and thin parts. Annealing some kinds of castings was known and practiced before 1847. This is abundantly proved by the witnesses, and various modes of annealing plain castings had been described by scientific writers both in this country and abroad, before that time. But there is no evidence that we have been able to discover that cast-iron car wheels had ever been subjected to an annealing process, in connection with slow cooling, before the process was invented or discovered by Whitney. In all the experiments made for annealing other castings the object sought was different, and in them all, as well as in the process described in the publications given in evidence, the effect on the annealed metal or glass was not to leave them in the condition in which it was sought to bring car wheels, with the crystallization or chill of the periphery unimpaired, and the plate or thin part unaf-

fected by strain. Cast-iron railroad wheels are castings of a peculiar kind. The methods of slow cooling, or of annealing and slow cooling, which were applied to other castings before 1849, were not adapted to their peculiarities, or to what they needed. They are not homogeneous throughout. They are of different thickness in their several parts, and hardened at the tread, while the plate and hub are not crystallized, but are soft and tough. These different qualities of the different parts it is necessary to preserve, and what was needed when Whitney's invention was made, was to preserve them, and at the same time relieve against any strain, caused by equal cooling, which might impair the strength of the wheel."

1000 *82 For the reasons we have stated, we are therefore of opinion that Whitney practice was not an anticipation. We are further of opinion that the Jones process was novel, and involved invention, and for reasons hereafter stated was the proper subject for a process patent. And in concluding this branch of the case we deem it proper to say that careful study and matured thought satisfies us that the Jones invention was a marked advance in the steel-maker's art. In other cases it has been held that if the change in question is one which would not occur to the practiced eye of the ordinary mechanic, such fact might tend to show that the step involved invention. But here was a step, a desideratum, which not the skill of the ordinary mechanic but the keenest intellect of men technically taught in the schools of different countries and practically trained at the furnace bosh was seeking for years to reach and failed to attain. A great industry was interested and alert upon the solution of the question. The evil was a recognized one, and was discussed at the gatherings of the master minds of that industry, but no one met it until the simple and effective key furnished by Jones unlocked the gate which had so long barred advance.

It is, however, further contended that the claim in issue is not a process within the meaning of the patent law, and therefore not patentable. An examination of the cases cited satisfy us that it is. Section 4486 R. S. authorizes the grant of a patent to any person who has invented or "discovered any new or useful art, * * * or any new and useful improvement thereof." Cochran *vs.* Deener, 94 U. S., 780, defined the term "art," as used in the statute to be synonymous with "process," and a process was defined to be "a mode of treatment of certain materials to produce a given result; an act or series of acts performed on a subject-matter to be transformed and reduced to a different state or thing." This is but a restatement in substance of what was so clearly stated in Corning *vs.* Burden, 15 Howard, 252: "It is for the discovery or

1000 *83 invention of some practicable method or means of producing a beneficial result or effect, that a patent is granted, and not for the result itself. It is when the term 'process' is used to represent the means or method of producing a result that is patentable, and it will include all methods or means which are not effected by mechanism or mechanical combinations."

These principles, (recognized in the Supreme Court of the United States, in Risdon *vs.* Medart, 158 U. S., 68) from the pens of two men who were singularly happy in stating in simple language the pith of an abstruse subject, are a safe guide in the somewhat abstruse field of process patents. Applying them to the case in hand, we see that the operation of Jones is a method of treatment as opposed to a mechanical operation. There is nothing mechanical in the relation of the tank to the fluid. The molten metal enters, a fluid: it leaves still a fluid; it is not diminished in quantity or affected in quality by any active, operative, mechanical operation of the enclosing tank. The tank is a mere envelope or chamber, whose purpose or function is to hold the fluid during the process. It is like the necessarily heavy boiler used in the process in Tilghman *vs.* Proctor, 102 U. S., 707; the furnace used in the process of annealing of Mowry *vs.* Whitney, 14 Wallace, 620, or the stove used in Neilson's Hot Blast, Webster's Rep., 312–371. The marrow and essence of the Jones operation lies, not in the enveloping vessel, but in the action of the enveloped fluid. That treatment, change, a new result take place between the fluid's entrance and its exit is clear. The change that takes place is both thermal and quasi-chemical in its nature; it is also of a kind or degree that can be effected in no other way than by passage through or incorporation with the enveloped fluid mass. The incoming charge loses its individual, constituent and thermal character; it merges then in the detained mass; it partakes of the character of each of the constituent portions of that mass when it enters it, and on its exit leaves its influence behind to affect, modify and grade each new incoming addition. It would seem from the nature of things that each resultant, outgoing charge was different from every incoming one, and, therefore, there must be change in the state, if not in the thing itself. In truth, in fact, in practical effect, the graduated, non-abrupt outgoing charge has changed from the moment of its entrance, and that change, all-important and vital, was wrought by operation of the bath, not by the vessel. If change of state or transformation without mechanism or mechanical operation be a test of process, the change here is more marked than that of the air in Neilson's hot blast. There the change was merely thermal, and the air could return to its original condition, here the change was not only thermal but constitutional or constituent. A different atomic, constituent body, designedly made so, was the result of Jones' treatment.

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The Neilson hot blast is cited in text books and reports as a case of typical process—see Tilghman *vs.* Proctor, 102 U. S., 707; O'Reilly *vs.* Morse, 15 How., 62. Accepting it as such, it may be described as a process for preparing air for use in blast furnace by first passing it through a dominant heating medium, whereby its thermal state is changed for functional purposes; while the Jones invention of the claim may be described as a process for preparing blast-furnace metal for use in a converter, by first passing it through a dominant pool of metal, whereby its thermal state and proportions of chemical constituents are changed for functional purposes. If

the law has rightly adjudged Neilson the inventor of a process, it should likewise adjudge Jones. While the former changed the nature of the blast alone, but did not, save in quantity, change the product itself, the other changed the very nature of the product and made it susceptible of more successful use in the direct Bessemer process.

Has infringement been shown? In this connection, the question of the apparatus employed is of importance only as bearing on its adaptability for the practice of the Jones process, for
1000 *85 infringement of process, not apparatus, is charged. Respondent's apparatus consists, since November, 1895, of a large, covered, refractory-lined vessel of about three hundred tons capacity, adapted to be tipped by hydraulic pressure, having a receiving hopper at the rear and a pouring spout at the front. Both a blast-furnace plant and a cupola system supply metal for its Bessemer converter plant, the former about two-thirds, the latter one-third, the metal used. It is to be noted that the cupola system continues, since the installation of the reservoir, to deliver its metal by ladle to the converter direct, and not through the reservoir. The metal from the blast furnace enters the receiver in approximately fifteen-ton ladle lots, and is withdrawn in approximately twelve-ton ladle ones. Mr. Joseph Morgan, Jr., chief engineer of the respondent company, states that "in accordance with the natural way of using a reservoir, it is ordinarily kept well filled up." The minimum amount maintained in respondent's reservoir is proved by Mr. Levi D. Upton, as follows:

"Q. Did you see any mark upon the mixer, and if so, was your attention called to it in any way?

A. My attention was called to a chalk-mark, which, by the way, I had noticed before, on the side of the mixer. They told me they didn't allow them to run that chalk-mark below the floor. When it came to the floor they still had retained in the mixer about 175 tons.

Q. Please state what you mean by the chalk-mark coming to the floor.

A. What they call the mixer floor, is where the men work to rotate or tilt the mixer, and if the mark they have on the mixer goes on the floor out of sight, they cannot tell how much they have left.

Q. Am I to understand you that the mixer was not to be tilted more than enough to bring the chalk-mark on a level with the mixer floor?

1000 *86 A. That is the meaning I wish to convey, and if they hadn't enough to make out their heat without going below the floor, they wait till they get more in.

Q. Who explained this to you?

A. The superintendent of the Bessemer department.

Q. What is his name?

A. F. G. Parker.

Q. I understand, then, if the chalk-mark did not go below the

level of the mixer floor there would be 175 tons of metal retained in the mixture. Is this correct?

A. Yes, sir."

Mr. Parker was not called to dispute this statement.

Mr. John E. Fry, an experienced theoretical and practical steel-maker, testifies to the operative process, as follows:

"On Monday, March 29, 1897, I saw the metal mixer used at the Cambria iron works. Its principle of construction is similar to the Jones mixer, and its operation is identical with that set forth in Jones' patent.

"When I saw it in use it contained a relatively large body of molten metal which had been brought to it from the blast furnaces while liquid, and relatively small portions of such metal were added to its contents from time to time, and other portions were poured from it into a charging ladle and taken to the converters for conversion into steel. In these operations, care was taken to maintain in the mixer a relatively large quantity of metal so that the portions added would remain for a sufficient time subject to the mixing effects of the mixer before being withdrawn. This to 'average up' the chemical constituents of the metal and make the fluctuations gradual as is done in the Jones method.

"Owing to, or in conformity with shop rules, the withdrawals of converter charges of mixed metals were made with approximate regularity of time intervals, and the additions and withdrawals were made as near as 'time about' as possible. The 1000 *87 additions were about one-fourth larger than the withdrawals, say five of the latter to four of the former so that the additions were balanced by the withdrawals.

"An oil vapor jet was used for heating the empty mixer preparatory to serving it with metal at the beginning of the week's work, but after a quantity of metal was added that was above the established minimum of one-half full, there was no further need for the vapor jet and it was shut off.

"The normal position of the mixer when not in use was upright, and in this position it received the additions of molten blast-furnace metal. In making a withdrawal the mixer was tipped or rocked forward, and it was returned to its normal condition when the withdrawal had been made. A mark was placed on the outside of the mixer so as to move relatively to the motion of the mixer in pouring out metal. This was a chalk-mark or white line, and in addition there was a graduated gauge-board. The mark was placed relative to a fixed point, so that about one-half the capacity of the mixer would represent the minimum amount of metal desired to be retained for mixing effects."

It is quite clear, in view of these facts, that infringement takes place. That initial mixing rather than storage is the purpose of the reservoir is shown by the fact that the cupola metal is not stored, but served direct in ladles to the converter plant. And that the homogeneous mixture once obtained is used as a dominant pool to produce a graduated, non-abrupt product, is shown by the chalk-

line minimum limit of one hundred and seventy-five tons. With such a permanent dominant pool in constant use, we are clear that respondent's practice infringes the second claim of the Jones patent in both letter and spirit. Indeed, Mr. Morgan himself says, "With the exception of additions of cupola metal, I do not know that there is any material difference between our practice and that described in the second claim." The exception noted can have no effect on the question of infringement. In substance, as carried on by respondents, it is a disconnected operation, wholly independent of the mixer. The only exception being where there was not sufficient cupola metal for a full converter charge the shortage was drawn from the mixer.

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For the reasons stated, we are of opinion that infringement of the second claim is shown.

As bearing on the question of the admission in evidence of the disclaimer filed in evidence, we are of opinion that there was no unreasonable neglect or delay in filing the same, and it was promptly called to the attention of the court and offered in evidence thereafter. We will admit it in evidence and in our consideration of the patent have so considered it. The power to disclaim is a beneficial one, and ought not to be denied, except where it is resorted to for a fraudulent and deceptive purpose; Sessions *vs.* Romadka, 145 U. S., 41; of which there is no proof in this case. Having been made after suit brought, the decree entered will be without costs. Smith *vs.* Nichols, 21 Wallace, 117.

Let a decree be prepared and submitted.

1000 *89

Petition on Appeal.

To the honorable the judges of the United States circuit court of appeals for the third circuit:

Appeal of The Cambria Iron Company, the above appellant, respectfully showeth:

That — the circuit court of the United States for the western district of Pennsylvania at No. 2 May term, 1896, in a suit in equity brought by The Carnegie Steel Company, Limited, complainant, against The Cambria Iron Company, defendant, on the 20th day of September, 1898, a decree was made and entered in said circuit court whereby it was adjudged and decreed that claim 2 of the letters patent sued upon in said cause, to wit, letters patent No. 404,414, granted to W. R. Jones, June 4, 1889, for alleged method of mixing molten metals, was valid and infringed by the said Cambria Iron Company, defendant, and an injunction was granted restraining the further infringement of said claim 2 of said letters patent, which decree granting said injunction is, as this appellant is advised and believes, erroneous and should be reversed. Wherefore this appellant feeling itself aggrieved by said decree hereby appeals from so much of said decree as grants and orders an injunction against this defendant to the United States circuit court of appeals for the third circuit, and respectfully prays that its appeal may be allowed, and that a transcript of said decree, and of the pleadings and proofs and other

proceedings relating to the granting of said decree, and such exhibits as may be necessary in hearing this appeal, may be transmitted to the said United States circuit court of appeals for the third circuit without delay, and that the said United States circuit court of appeals for the third circuit proceed to hear said cause, and that the decree of the said circuit court granting said injunction may be reversed. And it will ever pray, etc.

THE CAMBRIA IRON CO.,
By JAMES I. KAY, *Solicitor.*

1000 *90 *Petition on Appeal Allowed.*

And now, to wit, October 17th, 1898, the above appeal is allowed.

JOS. BUFFINGTON, *Judge.*

Assignments of Error.

And now, to wit, October 17th, 1898, come the appellants in the above cause, by their solicitors, and in connection with the appeal from so much of the interlocutory decree entered in the circuit court of the United States for the western district of Pennsylvania, on the 20th day of September, 1898, in the above cause as grants an injunction against this appellant, makes and files the following assignments of error, to wit, that the learned court below erred:

1st. In holding that the 2d claim of the Jones patent in suit was valid, and in granting the injunction thereunder; whereas, the court should have held the same invalid, and should therefore have refused the injunction.

2d. In holding that the practice followed by defendant was an infringement upon the 2d claim of the Jones patent in suit, and in granting the injunction restraining the use of the same; whereas, the court should have held that defendant's practice did not embody the invention covered by said claim, and should therefore have refused the injunction.

3d. In considering as valid and effectual the so-called disclaimer filed to the patent in suit, and in construing said patent as changed and modified by said so-called disclaimer, and in awarding an injunction on the patent thus constructed; whereas the court should have held said so-called disclaimer to be of a character not warranted or permitted by the statutory provisions relating to disclaimers; and as relevant, if at all, only as a confession by the complainant and owner of the patent that the invention
1000 *91 covered by the patent was not new or patentable; and should therefore have refused the injunction.

4th. In admitting in evidence the so called disclaimer filed to the patent in suit, and in construing the said patent as changed and modified by said so-called disclaimer, and in awarding an injunction on the patent thus construed; whereas the court should have refused to admit the same in evidence because it was not such disclaimer as provided for by statute, and should have refused to

consider the patent as modified thereby, and therefore should have refused the injunction.

5th. In considering as valid and effectual the so-called disclaimer filed to the patent in suit, and as construing said patent as changed and modified by said so-called disclaimer, and in awarding an injunction on the patent thus construed; whereas the court should have held said disclaimer illegal in that, if it changed the patent in scope, it added to the second claim of the patent an extra step not previously included in the process covered by said claim, to wit, the step of refining or Bessemerizing the mixed metal, which was the province of a reissue and not of a disclaimer.

6th. In deciding that the Whitney car-wheel practice as proven in the evidence was not a substantial anticipation of the alleged invention covered by the 2nd claim of the Jones patent, and in granting the injunction under such claim; whereas the court should have decided that it was not patentably distinguishable from said Whitney practice, and should therefore have refused the injunction.

7th. In deciding that practice at the car-wheel foundry of the Pennsylvania railroad at Altoona, Pennsylvania, as proven in the evidence, was not a substantial anticipation of the alleged invention covered by the 2nd claim of the Jones patent, and in granting the injunction under such claim; whereas the court should have decided that it was not patentably distinguishable from said Altoona practice, and should therefore have refused the injunction.

1000 *92 8th. In not deciding that the alleged invention covered by the 2nd claim of the Jones patent was anticipated by the publication found in Kirk's "Founding of Metals" proven in the cause; whereas the court should have decided that it was not patentably distinguishable from the practice described in said publication, and therefore have refused the injunction.

9th. In deciding that the American accumulating cupola-ladle practice in Bessemer steel works proven in the evidence, to wit, the practice at the Cambria, Lackawanna and Steelton mills, was not a substantial anticipation of the alleged invention covered by the 2d claim of the Jones patent, and in granting the injunction under such claim; whereas, it should have decided that it was not patentably distinguishable from such cupola-ladle practice, and should therefore have refused the injunction.

10th. In deciding that the Deighton English patent No. 3672 of 1873 was not a substantial anticipation of the alleged invention covered by the 2d claim of the Jones patent, and in granting the injunction under such claim; whereas, the court should have decided that said Deighton patent substantially anticipated the same, and should have therefore refused the injunction.

11th. In holding that the several publications describing the disclosures by G. J. Snelus, found in the British Institute Journals for the years 1874, 1875, 1878, and in Exhibit 1877 Holley Report, proven in evidence, were not substantial anticipation of the alleged invention covered by the 2d claim of the Jones patent; whereas the court should have decided that such several publications substan-

tially anticipated the same; and should therefore have refused the injunction.

12th. In deciding that the disclosures of Exhibit 1877 Holley Report, proven in evidence, were not substantial anticipation of the alleged invention covered by the 2d claim of the Jones

1000 *93 patent, and in granting the injunction under such claim; whereas the court should have decided that the disclosures of such Holley report substantially anticipated the same, and should therefore have refused the injunction.

13th. In holding that the alleged invention covered by the 2nd claim of the patent in suit disclosed patentable subject-matter, in view of the prior art as proven in evidence, and in granting the injunction under such claim; whereas the court should have decided that the 2nd claim of the Jones patent did not describe a patentably novel invention, in view of such prior art, and for this reason have refused the injunction.

14th. In not holding that if the alleged invention covered by the 2nd claim of the Jones patent was distinguishable in a patentable sense from the reservoirs described in the different publications proven in evidence, the practice in defendant's works was as fully distinguishable from such Jones invention, and did not infringe said Jones patent; and for this reason refusing the injunction.

15th. In deciding that the Tabberner English patent No. 2061 of 1856 was not a substantial anticipation of the alleged invention referred to, and covered by the 2nd claim of the Jones patent, and in granting the injunction under such claim; whereas the court should have decided that said Tabberner patent substantially anticipated the same, and should therefore have refused the injunction.

16th. In deciding that the Witherow U. S. patents Nos. 315,582 and 327,425 were not a substantial anticipation of the alleged invention covered by the 2nd claim of the Jones patent, and in granting the injunction under said claim; whereas the court should have decided that said Witherow patents substantially anticipated the same; and should therefore have refused the injunction.

17th. In not deciding that the Lohage U. S. patent No. 55442 was not a substantial anticipating of the alleged inven-

1000 *94 tion referred to in the 2d claim of the Jones patent, and for this reason refusing the injunction.

18th. In deciding that the practice at the Crescent steel works, Pittsburgh, proven in evidence, was not a substantial anticipation of the alleged invention covered by the 2d claim of the Jones patent, and in granting the injunction under such claim; whereas the court should have decided that said alleged invention was indistinguishable in a patentable sense from such practice at the Crescent steel works, and should therefore have refused the injunction.

19th. In deciding that the alleged invention covered by the 2d claim of the Jones patent set forth such a process as is contemplated, or is patentable under the statute relating to the granting of patents, and in granting the injunction under said claim; whereas the court

should have decided that it disclosed nothing patentable under the statute, and should for this reason have refused the injunction.

JAMES I. KAY,
Solicitor for Defendant and Appellant.

Service of the above assignment of errors acknowledged this 17th day of October, 1898.

THOMAS W. BAKEWELL,
Solicitor for Complainant.

Motion to Suspend Injunction.

And now, to wit, October 17, 1898, the above-named defendant, by its counsel, hereby shows to the court that defendant has perfected an appeal to the United States circuit court of appeals for the third circuit from so much of the interlocutory decree of this court entered September 20th, 1898, as ordered an injunction against this defendant, and therefore moves this honorable court for an order directing that the injunction heretofore ordered against this defendant, and all proceedings before the master in this cause,
1000 *95 be suspended pending the hearing and decision of the said circuit court of appeals in the appeal so taken.

THE CAMBRIA IRON CO.,
By JAMES I. KAY,
Of Counsel for Defendant.

To the Carnegie Steel Co., Limited, the above-named complainant, or Messrs. Bakewell & Bakewell, its solicitors:

Please take notice that on Monday, October 17th, 1898, the above motion will be presented to the United States circuit court for the western district of Pennsylvania.

JAMES I. KAY,
Of Counsel for Defendant.

Service of the above notice and motion, by a copy thereof, accepted this 14th day of October, 1898.

BAKEWELL & BAKEWELL,
Solicitors for Complainants.

Order Suspending Injunction.

And now, to wit, October 17, 1898, on hearing and due consideration of the motion on part of defendant to suspend the injunction and proceedings before the master in the above cause; it appearing that an appeal has been taken to the United States circuit court of appeals for the third circuit, from so much of the interlocutory decree in this cause as orders an injunction against the defendant: It is hereby ordered and decreed that the injunction heretofore ordered against the defendant in this cause, and all proceedings before the master therein, be, and the same are hereby, suspended pending the hearing and decision of said appeal in said circuit court

of appeals at the March term, 1899, provided, however, that if the hearing of said appeal be continued after said March
1000 *96 term, 1899, then this suspension shall terminate, unless renewed by this court, upon application to this court.

By the court:

JOS. BUFFINGTON, *Judge.*

Bond.

Know all men by these presents that we, The Cambria Iron Company, a corporation formed under the laws of the State of Pennsylvania, as principal, and Josiah M. Bacon, as surety, are held and firmly bound unto the above-named The Carnegie Steel Company, Limited, in the sum of one thousand ($1,000.00) dollars to be paid unto the Carnegie Steel Company, Limited, for payment of which well and truly to be made we do bind ourselves, and each of us, our and each of our heirs, executors, administrators and successors, jointly and severally, firmly by these presents.

Sealed with our seals this 12th day of October, 1898.

Whereas the above-named defendant, The Cambria Iron Company, has prosecuted an appeal to the United States circuit court of appeals for the third circuit to reverse the interlocutory decree rendered in the above-entitled suit by the judge of the United States circuit court for the western district of Pennsylvania, so far as said interlocutory decree relates to the granting of an injunction against said defendant.

Now, therefore, the condition of this obligation is such that if the above-named The Cambria Iron Company shall prosecute this appeal to effect, and answer all costs if it fails to make its appeal from the said interlocutory decree good, then this obligation shall be void, otherwise the same shall be and shall remain in full force and effect.

CAMBRIA IRON CO.
J. W. TOWNSEND, *V. P.*
JOSIAH M. BACON. [SEAL.]

Sealed and delivered in the presence of—
J. M. BACON,
As to signature of D. Stewart.

Attest: W. T. ROBINSON.

1000 *97 UNITED STATES OF AMERICA, } ss:
Eastern District of Pennsylvania, }

Josiah M. Bacon, being duly affirmed, deposes and says: I reside in Philadelphia, and am worth the sum of two thousand ($2,000.00) dollars and upwards, over and above all debts, liabilities, and property exempt from sale and execution.

JOSIAH M. BACON.

Affirmed to and subscribed before me this 12th day of October, 1898.

FRANCIS P. MALONE,
[SEAL.] *Notary Public.*

UNITED STATES OF AMERICA, }
Eastern District of Pennsylvania, } *ss:*

On this 12th day of October, 1898, before me personally came Josiah M. Bacon, to me known and known to be a director of the Cambria Iron Company, who executed the above bond as a director of the Cambria Iron Company and caused the corporate seal of said company to be thereunto affixed and acknowledged to me that he executed the same.

FRANCIS P. MALONE,
[SEAL.] *Notary Public.*

The above bond approved this 17th day of October, 1898.
JOS. BUFFINGTON, *Judge.*

Final Decree.

And now, to wit, September 20th, 1898, this cause came on to be heard at this term on final hearing, and the complainant having filed a disclaimer to a portion of said letters patent, which has been and is hereby admitted in evidence herein; thereupon, upon consideration thereof, it is ordered, adjudged and decreed that the letters patent in said complainant's bill mentioned, to wit: letters patent of the United States No. 404,414, dated June 4, 1889, for an improvement in methods of mixing molten pig metal, issued to William R. Jones, and assigned to the said complainant, The Carnegie Steel Company, Limited, as modified by said disclaimer, are as to the second claim thereof, said claim being the
1000 *98 only one in issue, a good and valid patent, the first claim having been withdrawn from consideration of the court; that the said William R. Jones was the first and original inventor of the improvement in said letters patent described and claimed in said second claim; that the said complainant is entitled to the exclusive right in and to the invention and improvement secured by the second claim of the said letters patent; that the said defendant by reason of the use of a certain method of mixing molten pig metal as in the said complainant's bill set forth, has infringed the said recited letters patent as to the second claim thereof, and has violated the exclusive rights of the said complainant thereunder; and that the said complainant do recover of it the said defendant all gains and profits by it made, and the damages sustained by complainant by reason of such infringement of said second claim, and that, by consent of the parties, it be referred to H. D. Gamble, Esq., residing at Pittsburg, Pa., as master, to ascertain the amount of such gains and profits, and of the damages sustained by the said complainant by reason of such infringement. And further, that a writ of injunction, according to the prayer of said bill, be issued from and under

the seal of this court, restraining and enjoining the defendant, its agents, employees, servants, workmen, and all others acting by and under its authority, from any further infringement of the second claim of the said recited letters patent; and of the exclusive rights of said complainant thereunder.

And it is further ordered, that the complainant, on such accounting, have the right to cause an examination of said defendant, *ore tenus*, or otherwise, and also the production of the books, vouchers and documents of the defendant, and that the said defendant attend for such purpose, before said master, from time to time as said master shall direct.

BY THE COURT.

1000 *99

Citation.

UNITED STATES OF AMERICA, *Western District of Pennsylvania*, } *ss:*

To the Carnegie Steel Company, Limited, Greeting:

You are hereby cited and admonished to be and appear at a session of the United States circuit court of appeals for the third circuit, to be holden at Philadelphia, in said circuit, on the 17th day of November next, pursuant to an appeal filed in the clerk's office of the circuit court of the United States for the western district of Pennsylvania, wherein The Cambria Iron Company is appellant, and you are appellee, to show cause, if any there be, why the decree rendered against the said appellant, as in the said appeal mentioned, should not be corrected and speedy justice done to the parties in this behalf.

Witness the Honorable Melville W. Fuller, Chief Justice of the Supreme Court of the United States, this 18th day of October, in the year of our Lord one thousand eight hundred and ninety-eight and of the Independence of the United States the one hundred and twenty-third.

JOS. BUFFINGTON, *Judge.*

Served upon Bakewell & Bakewell, Esqs., attorneys and solicitors for appellee, this 18th day of October, 1898.

H. D. GAMBLE.

Certificate.

WESTERN DISTRICT OF PENNSYLVANIA, *ss:*

I, H. D. Gamble, clerk of the circuit court of the United States, for the said district, do hereby certify that the annexed and foregoing pages contain a true copy of the record and proceedings in the above entitled case, so full and entire as the same remains of record and on file in my office.

In testimony whereof, I have hereunto signed my name and affixed the seal of the said court, at Pittsburgh, this 21st day of Nov., A. D. 1898.

[SEAL.]

H. D. GAMBLE, *Clerk.*

1001 FILE-WRAPPER AND CONTENTS OF PATENT NO. 404,414, TO WILLIAM R. JONES, DATED JUNE 4, 1889.

Petition.

To the Commissioner of Patents:

The petition of William R. Jones of Braddock in the county of Allegheny and State of Pennsylvania respectfully represents,

That your petitioner has invented a new and useful improvement in methods of mixing pig metal described and claimed in the annexed specification which he verily believes has not been known or used prior to the invention thereof by your petitioner; he therefore prays that letters patent of the United States may be granted to him therefor, vesting in him and his legal representatives, the exclusive right to the same upon the terms and conditions expressed in the act of Congress in that case made and provided: he having paid fifteen dollars into the Treasury, and complied with the other provisions of the said act.

He further prays that W. Bakewell, James K. Bakewell, and Thomas W. Bakewell, constituting the firm of W. Bakewell & Sons, of the city of Pittsburg, Pa., may be recognized as his attorneys in the matter of this application for a patent; hereby authorizing them, or their accredited agent, to transact all business with the office relative thereto; to sign the name of the petitioner to the drawings; to alter and amend the specification; to withdraw the application, or to appeal in case of rejection, as they may deem advisable; to receive the patent when granted, and generally to do all matters and things needful in the premises, as fully, and to all intents and purposes as your petitioner could do.

WILLIAM R. JONES.

Specification.

To all whom it may concern:

Be it known, that I, William R. Jones of Braddock, in the county of Allegheny and State of Pennsylvania have invented a new and useful improvement in methods of mixing molten pig metal and I do hereby declare the following to be a full, clear and exact description thereof.

1002 I shall describe my invention with reference to the accompanying drawings, in which

Figure 1 is a vertical longitudinal section of apparatus, which I have invented for practicing my invention.

Figure 2 is an end elevation of the mixing vessel and its actuating mechanism, viewed in the direction of the arrow *o* in figure 1.

Figure 3 is a plan view of the parts shown in figure 2.

Like symbols of reference indicate like parts in each.

Feb'y 18, '89.
Substitute B.

The primary object of the invention is to provide means for ensuring uniformity in the product of a Bessemer steel works or similar plant, in which the metal from [more than]* one or more a blast furnace is employed to charge the converters. The product of the different furnaces, or of the same furnace at different times, varies in quality, the variation depending on the kind of ore employed, and on many other conditions well known to those skilled in the art, so that when the converters are charged at one time with the output from one furnace, and at another time with the output from another furnace or furnaces, the manufactured steel lacks uniformity in grade. To avoid this I employ suitably constructed reservoirs or vessels, into which the molten metal from the blast furnaces is put, the vessels being of proper capacity to hold a considerable charge of metal from a single furnace, or from a number of furnaces, and being adapted to retain the metal in a molten state for sufficient time to enable the different charges to mix and become homogeneous. The advantage which I thus obtain in securing uniformity and homogeneity in the total product, will be readily understood by those familiar with the operations of a steel works and the frequent loss which is caused by the lack of such uniformity. Such apparatus possesses also an additional advantage in that it makes it possible to dispense with cupola furnaces for remelting the pigs preparatory to charging the converters. The metal may be tapped from the blast furnaces into ladles or trucks, carried to and discharged into the mixing reservoir or vessel, and there retained in a molten state until sufficient metal has been accumulated to charge the converters.

1005 Apr. 8, '89. My invention is not, [however,]* limited to its use in connection with converters, since similar advantages may be obtained by casting the metal from the mixing vessel into pigs for use in converters, puddling furnaces, or for any other uses to which pig iron may be put in the art.

Referring now to the drawings: 2 represents the reservoir before

[Matter enclosed between rules erased in copy.]
[* Words and figures enclosed in brackets erased in copy.]

mentioned. It consists of a covered hollow vessel, having an outer casting 3 of iron or steel, which is suitably braced and strengthened by exterior beams and tie-rods as shown in the drawings. The whole interior of the vessel is lined with firebrick or other refractory lining, which should be of sufficient thickness to retain the heat of the molten contents of the vessel, and to prevent chilling thereof. The vessel is strongly braced and supported by braces and tie-rods, and may be of any convenient size, holding say one hundred tons of metal, more or less, and its shape is preferably such as shown in the drawings, being rectangular, or nearly so, in cross-section, and an irregular trapezium in longitudinal section, one end being considerably deeper than the other. At the top of the deeper end, which I call the rear end, is a hopper 5, into which the molten metal employed in charging the vessel is poured, and at the front end is a discharging spout 6, which is so located that the bottom of the spout is some distance above the bottom of the vessel, say two feet in a hundred-ton tank, and more or less, according to the capacity of the vessel; the purpose of which is that when the metal is poured out of the spout, a considerable quantity may always be left remaining and unpoured, and that whenever the vessel is replenished there may already be contained in it a body of molten metal with which the fresh addition may mix. I thus secure, as much as possible, uniformity in character of the metal, which is fed to and discharged from the tank, and cause the fluctuations in quantity of the successive tappings to be very gradual. For convenient use of the apparatus, I have found it best to so ar-
1004 range it that it is adapted to receive its charges of metals from cars or bogies 7, which run on an elevated track at about the level of the normal position of the hopper 5, and to discharge its contents into similar cars or bogies 15, on a track below the spout 6. In order to facilitate the charging
journals or bearings
Feb. 18, '89. and discharging of the metal, the vessel is set on A [trunnions]* 8, which have their bearings in suitable pedestals 9, and its rear end is provided with depending rack bars 10, which are pivotally connected with the bottom of the mixing vessel 2, and are in gear with pinions 11, the shaft of which is connected by gearings 12 with the driving mechanism of a suitable engine. The pinions are held in gear with the rack bars by idler
journals or bearings
wheels or rollers 13. As the A [trunnions]* 8 are located on a transverse line somewhat in advance of the centre of gravity of the vessel, it tends by its own weight to tilt backwards into the position shown in figure 1, but may be restored to a level position by driving the pinions 11, and thus raising the rack bars 10 until the front part of the bottom of the vessel comes in contact with a rest or stop 14.

The mode of operation of the apparatus is as follows: When the vessel is in the backwardly inclined position shown in figure 1, it is ready to receive a charge of metal from the car 7. Before intro-

[* Words and figures enclosed in brackets erased in copy.]

ducing the first charge, however, the mixing vessel should be heated by internal combustion of coke or gas, and when the walls of the vessel are sufficiently hot to hold the molten metal without chilling it, it is charged repeatedly from the cars 7 with metal obtained either from a number of furnaces, or at different times from a single furnace. The charges of metal introduced at different times into the vessel, though differing in quality, mix together, and when the vessel has received a sufficient charge, its contents constitute a homogeneous molten mass, whose quality may not be precisely the same as that of any one of its constituent charges, but represents the average quality of all the charges. A The

1005

Insert B. [shape of the]* mixing [vessel]* (being deeper at its rear than at the front end, as before described,) and its normal position when not discharging metal for the purpose of casting, being with the bottom inclined upwards towards the front or discharging end, and the bottom of the spout being situate above the bottom of the vessel at its forward end, it is adapted to receive and hold a large quantity of molten metal without its surface rising high enough to enter the discharge spout.

Feb. 18, '89. The [hopper 5]* is furnished with a movable cover A [22,]* which when closed, serves to exclude the outside air, and prevent A [the]* rapid cooling of the molten contents. If care is exercised in keeping the cover closed [when the mixer 2 is not being charged,]* the metal can be kept in a fluid condition for a long time; the heat being kept up by repeated fresh charges of molten metal, and if necessary or found desirable, by burning gas introduced by a pipe or pipes into its interior.

After the vessel is properly charged, the metal is drawn off into the cars 15, from time to time, as it is needed, by opening the door or [valve]* 16, of the spout 6, and driving the engine 12, so as to elevate the rear end of the vessel, and tilt it forward, and thus to discharge any required amount of its contents in the manner before explained into the cars 15, which are transported to the converters or the metal is cast into pigs or otherwise used. The tilting of the vessel does not, however, drain off all the contents thereof, a portion being prevented from escaping by reason of the elevated position of the spout *e*, and as the vessel is replenished from time to time, each new charge mixes with parts of previous charges remaining in the vessel, by which means any sudden variations in the quality of the metal supplied to the converter is avoided. Instead of discharging the metal into the cars 12, and carrying it in the cars to the

1006 converters or casting-house, the vessel 2 may be so situate relatively to the other parts of the furnace as to deliver its

[* Words and figures enclosed in brackets erased in copy.]

Insert B².

contents immediately to the converters, or other place where it is to be utilized. A

Feb. 18, '89.

I shall now describe briefly other parts of the apparatus which are desirable and important in its practical use, [but which do not form essential features thereof.]* At the top of the vessel 2, are manholes 17, designed to permit of access to its interior for the purpose of repairing or fixing the lining. These holes are provided with suitable covers 18, to exclude cold draughts of air from entering the interior. There is also a hole 19 at the rear end of the vessel near the top, through which a rabble may be inserted for the purpose of assisting or accelerating the mixing of the molten metal; and at the other end, at the level of the bottom of the interior, there are holes 20 provided with suitable spouts to enable all the molten contents to be drawn off when it becomes necessary to do so (see figure 3). The hole 20 should be provided with suitable stoppers.

April 8, '89.

The main feature of my present invention is the method of storing successive charges of molten metal in a receptacle before using it in converters or otherwise, drawing portions of the metal from the receptacle without at any time removing the whole thereof, and from time to time replenishing the receptacle with fresh charges which mingle with the residual molten metal already therein, for the purpose of rendering the successive tappings of metal uniform in quality; and while I have shown and described apparatus well adapted to the practice of this method, I do not limit myself solely to its use, since modifications in the apparatus employed may be devised by those skilled in the art. The apparatus illustrated in the drawings is made the subject of a separate patent application No. 289,673, and I do not therefore claim it specifically herein, but what I do claim as my invention is:

Feb'y 18, '89.

[Matter enclosed between rules erased in copy.]
[* Words and figures enclosed in brackets erased in copy.]

Substitute Bf.

1007 The process hereinbefore described, which consists in storing charges of molten metal in a covered receptacle provided with a heat-retaining lining, removing portions only of the molten contents of the said receptacle without entirely draining or emptying the same, and successively replenishing the receptacle with fresh additions of molten metal, whereby the character of the several charges of metal so treated is equalized; substantially as described.

In testimony whereof, I have hereunto set my hand this ninth day of August, A. D. 1888.

WILLIAM R. JONES.

Witness:
E. J. SMAIL.
W. BAKEWELL.

Oath.

STATE OF PENNSYLVANIA, } ss:
County of Allegheny, }

William R. Jones, the above-named petitioner, a citizen of the United States and resident of Braddock, in the county of Allegheny and State of Pennsylvania, being duly sworn, deposes and says that he verily believes himself to be the original, sole and first inventor of the improvement in method of mixing molten pig metal described and claimed in the foregoing specification; that the same has not been patented to him, or to others with his knowledge or consent, in any country; that the same has not to his knowledge been in public use or on sale in the United States for more than two years prior to this application; and that he does not know and does not believe that the same was ever known or used prior to his invention thereof.

WILLIAM R. JONES.

Sworn to and subscribed before me this 9th day of August, 1888.

E. J. SMAIL,
Notary Public.

[L. S.]

1008 *Patent Office Letter of Dec.* 29, 1888.

This application has been considered.

The process seems to be completely anticipated by U. S. patent No. 315,587, Witherow, April 14, 1885, and No. 327,425, Witherow,

[Matter enclosed between rules erased in copy.]

Sept. 29, 1885 (converters); see also Kirk, "founding of metals,' page 19, New York, 1881.

F. P. MacLEAN,
Examiner, Division III.

Amendment of Feb. 16, 1889.

To the Commissioner of Patents.

SIR: We desire to amend the specification and claim of the above case, as follows:

Page 2, line 12, erase "more than one" and insert "*one or more.*"

Page 4, line 25, erase "trunnions" and substitute "*journals or bearings,*" and make same change on page 5, line 5.

Page 6, line 9, erase "the hopper 5" and insert "*the discharge spout 6.*"

Page 6, line 9, erase "22" and insert "operated *by a weighted lever 16.*"

Page 6, line 10, after word "prevent" insert "*a draft of air through the vessel and the consequent.*"

Page 6, line 12, erase "when the mixer 2 is not being charged."

Page 6, line 19, erase "valve" and insert "cover."

Page 7, lines 11 and 12, erase "but which do not form essential features thereof."

Page 8, after "serial No." insert "289,673."

1009 Erase the claim as presented and insert the following:

"A."

Insert B³.

"The process hereinbefore described, which consists in running successive charges of molten metal into a covered receptacle provided with a heat-retaining lining, removing from time to time from said receptacle for subsequent treatment a portion only of its molten contents, and successively replenishing such receptacle with fresh additions of molten metal, for the purpose of equalizing the character of the several charges of metal drawn therefrom, substantially as described."

Argument.

We file herewith amendments to the specification and an amended claim, in view of which I respectfully request a reconsideration.

I have examined with care the references cited and respectfully submit that the case, as now amended, is not met by any of them.

The purpose of the Witherow patent No. 327,425 is to receive and

[Matter enclosed between rules erased in copy.]

store the molten metal for the purpose of preventing the detention incident to the necessity of discharging the contents of the blast furnace when there is no converter ready to receive it. The idea of the patent is not to mix the metal gradually by having a receptable into which various charges of molten metal are run and from which the metal is withdrawn from time to time as needed for the converters. The use of his apparatus could not and would not result in a mixing of the metal drawn from several blast furnaces.

On the other hand the distinctive idea of the Jones application is to have a receptable capable of holding metal in a molten condition into which, metal, it may be, from several blast furnaces is run from time to time and from which metal is drawn for treatment in the converters or otherwise as required. This continual pouring into and drawing out of a common receptacle produces such
1010 a mixing of the charges as results in an uniform average quality of metal whether treated in the converters or used for casting without such treatment, as is very desirable, and has been hitherto found to be practically unattainable.

As to the statement found in Kirk's founding of metals, of the practice of all the foundries in Wheeling, W. Va., I submit that while it is possible with a previous knowledge of the Jones method to find some apparent similarity, yet it is impossible to read into the Kirk description the Jones invention, and the fact remains that whatever Kirk may refer to, the process described by Jones is not and never has been, so far as we are informed, in use in the foundries in that city.

For these reasons, we trust that there will be no difficulty in allowing the claim as now presented.

Very respectfully,

W. BAKEWELL & SONS,
W. BAKEWELL,
Att'ys for Jones.

Pittsburg, Feb. 16, 1889.

Patent Office Letter of Feb. 23, 1889.

This application has been reconsidered as amended.

The process, as now claimed, seems to be fully met by the description in Kirk's metal founding, heretofore referred to, which states that the metal is run continuously from the cupola and mixed in the ladle, from which it is tapped into the smaller ladle. See also the additional references of British patents No. 859, Broman, March 23, 1866, page 5, lines 25–35, and No. 2382, Stewart, May 10, 1883, page 5, lines 9 and 10.

F. P. MacLEAN,
Examiner, Div. III.

1011 *Amendment of March* 30, 1889.

PITTSBURG, *March* 30, 1889.

The Commissioner of Patents.

SIR: This case is amended as follows:

Page 2, line 10, cancel from beginning of this line to end of line 11, page 3, and insert:

B. The primary object of my invention is to provide means for rendering the product of steel works uniform in chemical composition. In practice it is found that metal tapped from different blast furnaces is apt to vary considerably in chemical composition, particularly in silicon and sulphur, and such lack of uniformity is observable in different portions of the same cast, and even in different portions of the same pig. The following table, giving the analyses of metal contained in different ladle charges, tapped from a blast furnace at a single casting at the Edgar Thomson steel works, Braddock, Pennsylvania, will illustrate the fact:

Ladle No. 1 contained silicon 4.15 per cent., sulphur .015 per cent.

Ladle No. 2 contained silicon 4.07 per cent., sulphur .025 per cent.

Ladle No. 3 contained silicon 2.89 per cent., sulphur .030 per cent.

Ladle No. 5 contained silicon 1.23 per cent., sulphur .120 per cent.

Ladle No. 6 contained silicon 2.52 per cent., sulphur .061 per cent.

Ladle No. 7 contained silicon .66 per cent., sulphur .143 per cent.

The consequence of this tendency of the silicon and sulphur to segregate or form pockets in the crude metal is that the product of the refining process in the converters or otherwise in like manner lacks uniformity in these elements, and therefore often causes great inconvenience and loss, making it impossible to manufacture all the articles of a single
1012 order of homogeneous composition. Especially is this so in the process of refining crude iron taken from the smelting furnace and charged directly into the converter without remelting in a cupola, and although such direct process possesses many economic advantages it has on this account been little practiced.

For the purpose of avoiding the practical evils above stated, I use the refining process, a charge composed not merely of metal taken at one time from the smelting furnace, but of a number of parts taken from different smelting furnaces or from the same furnace at different casts or at different periods of the same cast, and subject the metal before its final

refining, to a process of mixing, whereby its particles are diffused or mingled thoroughly among each other, and the entire charge is practically homogeneous in composition, representing in each part the average of the unequally diffused and segregated elements of silicon and sulphur originally contained in each of the several parts or charges. By proceeding in this way, not only is each charge for the refining furnace or converter homogeneous in itself, but as it represents an average of a variety of ununiform constituent parts, all the charges of the converter from time to time will be substantially uniform, and the products of all will be homogeneous. To this end, my invention may be practiced with a variety of forms of apparatus, for example, by merely receiving in a charging ladle, a number of small portions of metal taken from several ladles or receiving vessels containing crude metal obtained at different times from different furnaces, the mixing being performed merely by the act of pouring into the charging ladle, and other like means may be employed. I prefer, however, to employ the apparatus shown in the accompanying drawings, and have made it the subject of a separate patent application, serial No. 289,673, and without intending to limit the invention to the use of that specific apparatus, I shall describe it particularly, so that others skilled in the art may intelligently employ the same.

1013

Page 3, line 12, cancel "however."

Page 5, last line, after "charges" insert:

B¹. If desired, the commingling of the contents may be aided by agitation of the vessel on its trunnions, so as to cause the stirring or shaking of its liquid contents.

Page 7, line 9, after "utilize," insert:

B². I find it in practice very advantageous to employ two or more mixing vessels constructed substantially as I have described, and to draw a portion of each converter charge from each of the mixing vessels. My invention is, however, not limited to the employment of two or any specific number of such vessels.

Page 7, 3d line from bottom of page, cancel from "the main," inclusive to end of specification, including claims, and insert:

I claim:

B³. 1. In the art of refining iron directly from the smelting furnace, the process of equalizing the chemical composition of the crude metal, by thoroughly commingling or mixing together the liquid metal charge, and subsequently refining

the mixed and equalized charge; substantially as and for the purposes described.

2. In the art of mixing molten metal to secure uniformity of the same in its constituent parts, preparatory to further treatment, the process of introducing into a mixing receptacle, successive portions of molten metal ununiform in their non-metallic constituents (sulphur, silicon, etc.,) removing portions only of the composite molten contents of the receptacle without entirely draining or emptying the same, and successively replenishing the receptacle with fresh ununiform additions; substantially as and for the purposes described.

A reconsideration is requested.

Very respectfully, W. BAKEWELL & SONS,
Attorneys for W. R. Jones.

1014 STATE OF PENNSYLVANIA, }
County of Allegheny, } *ss:*

William R. Jones, whose application for letters patent for an improvement in method of mixing molten pig metal (serial No. 289,672) was filed in the United States Patent Office on or about the 31st day of October, 1888, being duly sworn, deposes and says that he verily believes himself to be the original and first inventor of the improvement as described and claimed in the foregoing amendment, as well as of that which was embraced in the claims originally made, and that he does not know and does not believe that the same was ever before known or used, and that the matter sought to be inserted formed a part of his original invention at the date of filing said application. Deponent further says that he has examined carefully the said amendment, and that the statements of facts concerning the unequal composition of the product of blast furnaces are true. The invention which is the subject of this application has been put into practical use at the Edgar Thomson steel works of Carnegie Brothers & Co., Limited, at Braddock, Pa., and has been found to be of very great practical value, securing uniformity in the product of the steel works, and thus rendering the same much more certain in character, and more valuable commercially.

WILLIAM R. JONES.

Sworn and subscribed before me this 5th day of April, 1889.

[L. S.] W. B. CORWIN,
Notary Public.

1015 *Circular of Allowance.*

Serial No., 289,672.

DEPARTMENT OF THE INTERIOR,
U. S. PATENT OFFICE,
WASHINGTON, D. C., *May* 6, 1889.

William R. Jones, care W. Bakewell & Sons, Pittsburgh, Pa.

SIR: Your application for a patent for improvement in method of mining molten pig metal, filed October 31, 1888, has been examined and allowed.

The final fee, twenty dollars, must be paid, and the letters patent bear date as of a day not later than six months from the time of this present notice of allowance.

If the final fee is not paid within that period the patent will be withheld, and your only relief will be by a renewal of the application, with additional fees, under the provisions of section 4897, Revised Statutes. The office aims to deliver patents upon the day of their date, and on which their term begins to run; but to do this properly applicants will be expected to pay their final fees at least twenty days prior to the conclusion of the six months allowed them by law. The printing, photolithographing, and engrossing of the several patent parts, preparatory to final signing and sealing, will consume the intervening time, and such work will not be done until after payment of the necessary fees.

When you send the final fee you will also send, distinctly and plainly written, the name of the inventor and title of invention as above given, date of allowance (which is the date of this circular), date of filing, and, if assigned, the names of the assignees.

[Printed across the face:] ☞ In remitting the final fee give the serial number at the head of this notice.

1016 If you desire to have the patent issue to assignees, an assignment containing a request to that effect, together with the fee for recording the same, must be filed in this office on or before the date of payment of final fee.

Additional copies of specifications and drawings will be charged for at the following rates: Single copies, uncertified, 25 cents; 20 copies or more, 10 cents each. The money should accompany the order.

Very respectfully, C. E. MITCHELL,
Commissioner of Patents.

The within title is that given by the examiner in charge, as most appropriate to your invention. Should you desire a change in the same, satisfactory reasons must be given therefor on or before the payment of the final fee.

Memorandum of Fee Paid at U. S. Patent Office.

Amount received, $20. Chief clerk. Serial No., 289,672. Inventor: William R. Jones. Patent to be issued to William R. Jones. Name of invention as allowed: Method of mixing molten pig metal. Date of payment: ——. Fee: Final fee 20. Date of filing: ——. Date of circular of allowance: ——. The Commissioner of Patents will please apply the accompanying fee as indicated above.

W. BAKEWELL & SONS, *Attorneys.*

Send patent to W. Bakewell & Sons, Pittsburg, Pa.

U. S. Patent Office, May 11, 1889.

1017 Ex'r's Book, 40570, div. 3.

(Serial number) 289,672; patent No. 404,414.

William R. Jones,
Of Braddock,
County of ——,
State of Pennsylvania.
Invention: Method of mixing molten pig metal.

Parts of application filed.
- Petition, Oct. 31, 1888.
- Affidavit, " " "
- Specification, " " "
- Drawing, 2 sh'ts, " " "
- Model not required.
- Specimen, none.
- First fee, cash, $15, Oct. 31, '88.
- " " cert., ——.

App. filed complete Oct. 31, 1888.
Ack'l'd Nov. 2, '88.
May 4, 1889.
Examined: F. P. MacLean, ex. div. 3.
Countersigned: J. W. Babson, for Commissioner.
May 6, '89.
Notice of allowance, May 6, 1889.
Final fee, cash, $20, May 11, 1889.
" " cert., ——, 188–.
Patented June 4, 1889.
Att'y or P. O. address, W. Bakewell & Sons, Pittsburg, Pa.

1888.

Contents.

½. Application, — papers.
1. Dec. 29, 1888, letter.
2. Feb. 18, '89, amend't "A."
3. Feb. 23d, '89, letter.
4. Apr. 8, '89, amend't B & oath.
11. 75. Metallurgy converters.

Title: Improvement in the method of mixing molten pig metal.

1018 FILE-WRAPPER AND CONTENTS OF PATENT NO. 404,415, OF WILLIAM R. JONES, DATED JUNE 4, 1889.

Petition.

$15.

To the Commissioner of Patents:

The petition of William R. Jones, of Braddock, in the county of Allegheny and State of Pennsylvania, respectfully represents:

That your petitioner has invented a new and useful improvement in apparatus for mixing molten pig metal, described and claimed in the annexed specification which he verily believes has not been known or used prior to the invention thereof by your petitioner. He, therefore, prays that letters patent of United States may be granted to him therefor, vesting in him and his legal representatives, the exclusive right to the same upon the terms and conditions expressed in the act of Congress in that case made and provided. He having paid fifteen dollars into the Treasury, and complied with the other provisions of the said act.

He further prays that W. Bakewell, James K. Bakewell and Thomas W. Bakewell, constituting the firm of W. Bakewell & Sons, of the city of Pittsburg, Pa., may be recognized as his attorneys in the matter of this application for a patent; hereby authorizing them, or their accredited agent, to transact all business with the office relative thereto; to sign the name of the petitioner to the drawings; to alter and amend the specification; to withdraw the application, or to appeal in case of rejection, as they may deem advisable; to receive the patent when granted, and generally to do all matters and things needful in the premises, as fully, and to all intents and purposes as your petitioner could do.

WILLIAM R. JONES.

1019 *Specification.*

To all whom it may concern:

Be it known, that I, William R. Jones, of Braddock, in the county of Allegheny and State of Pennsylvania, have invented a new and useful improvement in apparatus for mixing molten pig metal, and I do hereby declare the following to be a full, clear and exact description thereof:

I shall describe my invention with reference to the accompanying drawings, in which

Figure 1 is a vertical longitudinal section of my approved apparatus.

Figure 2 is an end elevation of the mixing vessel and its actuating mechanism, viewed in the direction of the arrow *A* of figure 1.

Figure 3 is a plan view of the parts shown in figure 2.

Like symbols of reference indicate like parts in each.

The primary object of the invention is to provide means for ensuring uniformity in the product of a Bessemer steel works or a similar plant, in which the metal from a more [than one]* blast furnace is employed to charge the converters. The product of different furnaces or of the same furnace at different times, varies in quality, the variation depending on the kind of ore employed, and on many other conditions well known to those skilled in the art, so that when the converters are charged at one time with the output from one furnace, and at another time with the output from another furnace or furnaces, the manufactured steel lacks uniformity in grade. To avoid this, I employ suitably constructed reservoirs or vessels, into which the molten metal from the blast furnaces is put, the vessels being of proper capacity to hold a considerable charge of metal from a single furnace or from a number of furnaces, and being adapted to retain the metal in a molten state for a sufficient time to enable the different charges to mix and become homogeneous. The advantage which I thus obtain in securing uniformity and homogeneity in the total product will be readily understood by those familiar with the operations of a steel works and the frequent loss which is caused by the lack of such uniformity. Such apparatus possesses also an additional advantage in that it makes it possible to dispense with cupola furnaces for remelting the pigs preparatory to charging the converters. The metal may be tapped from the blast furnaces into ladles or trucks, carried to and discharged into the mixing reservoir or vessel, and there retained in a molten state until sufficient metal has been accumulated to charge the converters.

Jan. 24, '89.

1020

My invention is not, however, limited to its use in connection with converters, since similar advantages may be obtained by casting the metal from the mixing vessel into pigs for use in converters, puddling furnaces, or for any other uses to which pig iron may be put in the art.

Referring now to the drawings—2 represents the reservoir before mentioned. It consists of a covered hollow vessel, having an outer casting 3, of iron or steel which is suitably braced and strengthened, by exterior beams and the rods as shown in the drawings. The whole interior of the vessel is lined with firebrick or other refractory lining, which should be of sufficient thickness to retain the heat of the molten contents of the vessel, and to prevent chilling thereof. The vessel is strongly braced and supported by braces and tie-rods, and may be of any convenient size, holding say one hundred tons of metal, more or less, and its shape is preferably such as shown in the drawings, being rectangular or nearly so in cross-section, and an irregular trapezium in longitudinal section, one end being considerably deeper than the other. At the top of the deeper end, which I call the rear end, is a hopper 5, into which the molten metal employed in charging the vessel is poured, and at the front

[* Words and figures enclosed in brackets erased in copy.]

end is a discharge spout 6, which is so located that the bottom of the spout is some distance above the bottom of the vessel, say
1021 two feet in a hundred-ton tank, and more or less according to the capacity of the vessel; the purpose of which is that when the metal is poured out of the spout, a considerable quantity may always be left remaining and unpoured, and that whenever the vessel is replenished there may already be contained in it a body of molten metal with which the fresh addition may mix. I thus secure, as much as possible, uniformity in character of the metal, which is fed to and discharged from the tank, and cause the fluctuations in quantity of the successive tappings to be very gradual. For convenient use of the apparatus, I have found it best to so arrange it that it is adapted to receive its charges of metals from cars or bogies 7, which run on an elevated track at about the normal position of the hopper 5, and to discharge its contents into similar cars or bogies 15, on a track below the spout 6. In order to facilitate the charging and discharging of the

journals or bearings

Jan'y 24, '89. metal, the vessel is set on A [trunnions]* 8, which have their bearings in suitable pedestals 9, and its rear end is provided with depending rack bars 10, which are pivotally connected with the bottom of the mixing vessel 2, and are in gear with pinions 11, the shaft of which is connected by gearings 12, with the driving mechanism of a suitable engine. The pinions are held in gear with the rack bars by

journals or bearings

Jan'y 24, '89. idler wheels or rollers 13. As the A [trunnions]* 8 are located on a transverse line somewhat in advance of the centre of gravity of the vessel, it tends by its own weight to tilt backwards into the position shown in figure 1, but may be restored to a level position by driving the pinions 11, and thus raising the rack bars 10 until the front part of the bottom of the vessel comes in contact with a rest or stop 14.

The mode of operation of the apparatus is as follows:

When the vessel is in the backwardly inclined position shown in figure 1, it is ready to receive a charge of metal from the car 7. Before introducing the first charge, however, the mixing
1022 vessel should be heated by internal combustion of coke or gas, and when the walls of the vessel are sufficiently hot to hold the molten metal without chilling it, it is charged repeatedly from the cars 7 with metal obtained either from a number of furnaces, or at different times from a single furnace. The charges of metal introduced at different times into the vessel, though differing in quality, mix together, and when the vessel has received a sufficient charge, its contents constitute a homogeneous molten mass, whose quality may not be precisely the same as that of any one of its constituent excharges, but represents the average quality of all the charges. The mixing chamber being deeper at its rear than at the front end, as before described, and its normal position when not discharging metal for the purpose of casting, being with the bottom

[* Words and figures enclosed in brackets erased in copy.]

inclined upwards towards the front or discharging end, and the bottom of the spout being situate above the bottom of the vessel at its forward end, it is adapted to receive and hold a large quantity of molten metal without its surface rising high enough to enter the discharge spout.

Jan'y 24, '89. The A [hopper 5]* is furnished with a movable cover A [22,]* which when closed, serves to exclude the outside air, and prevent A the rapid cooling of the molten contents. If care is exercised in keeping the cover closed [when the mixer 2 is not being charged]* the metal can be kept in a fluid condition for a long time; the heat being kept up by repeated fresh charges of molten metal, and if necessary or found desirable, by burning gas introduced by a pipe or pipes into its interior. After the vessel is properly charged the metal is drawn off into the cars 15, from time to time, as it is needed, by opening the door or A [valve]* 16 of the spout 6, and driving the engine 12, so as to elevate the rear end of the vessel and tilt it forward, and thus to discharge any required amount of its contents in the manner before explained into the cars 15, which are transported to the con-
1023 verters or the metal is cast into pigs or otherwise used. The tilting of the vessel does not, however, drain off all the contents thereof, a portion being prevented from escaping by reason of the elevated position of the spout 6, and as the vessel is replenished from time to time each new charge mixes with parts of previous charges remaining in the vessel, by which means any sudden variation in the quality of the metal supplied to the converter is avoided. Instead of discharging the metal into the cars 12 and carrying it in the cars to the converters or casting-house, the vessel 2 may be so situate relatively to the other parts of a furnace plant as to deliver its contents immediately to the converters, or other place where it is to be utilized.

I shall now describe briefly other parts of the apparatus which are desirable and important in its practical use,

Jan'y 24, '89. [but which do not form essential features thereof.]* At the top of the vessel 2, are manholes 17, designed to permit of access to its interior for the purpose of repairing or fixing the lining. These holes are provided with suitable covers 18, to exclude cold draughts of air, from entering the interior. There is also a hole 19 at the rear end of the vessel near the top, through which a rabble may be inserted for the purpose of assisting or accelerating the mixing of the molten metal; and at the other end, at the level of the bottom of the interior, there are holes 20, provided with suitable spouts to enable all the molten contents to be drawn off when it becomes necessary to do so (see figure 3). The holes 20 should be provided with suitable stoppers.

[* Words and figures enclosed in brackets erased in copy.]

D. 12, '88.

1024 The main feature of the present invention is broadly a covered preliminary receiving vessel for holding and mixing the charges of molten metal which are supplied thereto, either from a blast furnace or cupola, and I intend to cover the same, whether the receptacle be tilting, or stationary, or whatever be its location. The subordinate feature of my invention are sufficiently indicated in the following claims. I do not herein claim the method, as such, for storing charges of molten metal in a receptacle before employing it in converters or otherwise, and at intervals tapping or drawing off portions only of the molten contents and replenishing the same with fresh charges, since I have embodied such method in a separate patent application, serial No., 289,672.

Cancelled Jan'y 24, '89.

I do not desire to limit myself to the precise form of the apparatus which I have shown and described since many modifications in form and relative location of the parts may be made by the skilled mechanic, but what I claim is—

Cancelled Jan'y 24, '89.

1. An apparatus for receiving and mixing successive charges of molten metal previous to its further treatment or use, consisting in a covered vessel or receptacle having a refractory and heat-retaining lining, and provided with a charging hole and a discharging hole

Substitute B, Jan'y 24, '89.

from which the bottom of said vessel or receptacle is downwardly inclined

D. 12, '88.

or tap A substantially as described.

2. An apparatus for receiving and mixing successive charges of molten metal previous to its further treatment or use, consisting in a covered vessel or receptacle, having a charging hole through which the molten metal is introduced and an elevated discharging hole or tap, substantially as described.

Insert A, D. 12, '88.

3. An apparatus for receiving and mixing successive charges of molten metal previous to its further treatment or use, consisting in a covered tilting vessel or receptacle having a charging hole through which the molten metal is introduced and an elevated discharging hole or tap, substantially as and for the purposes described.

[Matter enclosed between rules erased in copy.]

Insert A, D. 12, '88.

1025 4. An apparatus for receiving and mixing successive charges of molten metal previous to its further treatment or use, consisting in a covered vessel or receptacle having a charging hole through which the molten metal is introduced an elevated discharging hole or tap, and a hole or holes at the base of the vessel for draining the same, substantially as and for the purposes described.

5. An apparatus for receiving and mixing successive charges of molten metal previous to its further treatment or use, consisting in a covered vessel or receptacle having a charging hole through which the molten metal is introduced, an elevated discharging hole or tap, and a hole or holes at the base of the vessel for draining the same, the bottom of said vessel being inclined backwardly from the discharge hole or tap, substantially as described.

Substitute B, Jan'y 24, '89.

Insert A², D. 12, '88.>

In testimony whereof I have hereunto set my hand this 9th day of August, A. D. 1888.

WM. R. JONES.

Witnesses:
E. J. SMAIL.
W. BAKEWELL.

Oath.

STATE OF PENNSYLVANIA, } ss:
County of Allegheny, }

William R. Jones, the above-named petitioner, a citizen of the United States, and resident of Braddock, in the county of Allegheny, and State of Pennsylvania, being duly sworn, deposes and says that he verily believes himself to be the original, sole and first inventor of the improvement in apparatus for mixing molten pig metal, described and claimed in the foregoing specification; that the same has not been patented to him, or to others with his knowledge or consent, in any country; that the same has not to his knowledge been in public use or on sale in the United States
1026 for more than two years prior to this application; and that he does not know and does not believe that the same was ever known or used prior to his invention thereof.

WM. R. JONES.

[Matter enclosed between rules erased in copy.]

Sworn to and subscribed before me this 9th day of August, 1888.

E. J. SMAIL,
[L. S.] *Notary Public.*

Patent Office Letter of December 1, 1888.

This application has been considered.

Claims 1 and 3 are met by U. S. patents Nos. 327,425, Witherow, Sept. 29, 1885, (converters); 238,110, Hainsworth, Feb. 22, 1881, and 284,005, Hainsworth, Aug. 28, 1883, (Class 22. Metal founding: In metal molds, ingots, plants).

Claim 4 is met in U. S. patents Nos. 381,119, Devereux, April 17, 1888, and 384,349, Devereux, June 12, 1888, (reducing and separating).

F. P. MACLEAN,
Examiner, Division III.

Amendment of Dec. 8, 1888.

PITTSBURG, *December 8th*, 1888.

To the Commissioner of Patents.

SIR: This case is amended as follows:

Claim 1, line 5, before "substantially," insert

> from which the bottom of said vessel or receptacle is downwardly inclined.

Cancel claim 3, and insert:

> 3. An apparatus for receiving and mixing successive charges of molten metal, previous to its further treatment or use, consisting in a covered vessel or receptacle provided with a discharge opening and mounted on permanent pivotal supports, and a power engine connected with the said vessel or receptacle for tilting the same; substantially as and for the purposes described.

[Matter enclosed between rules erased in copy.]

1027 Cancel claim 4, and insert:

> 4. An apparatus for receiving and mixing successive charges of molten metal, previous to its further treatment or use, consisting in a covered tilting vessel or receptacle having a charging hole through which at one end the molten metal is introduced, and a discharging hole or tap, at the opposite end, and a stop which limits the tilting of said vessel or receptacle to prevent discharge of the entire contents when in use; substantially as and for the purposes described.

Add the following claim:

> 6. An apparatus for receiving and mixing successive charges of molten metal, previous to its further treatment or use, consisting in a covered refractory lined vessel or receptacle having a discharge hole or tap, with a removable cover, a charging hole, substantially as and for the purposes described.

Page 7, line 17, cancel from beginning of this line to end of sentence on line 23 of page 7.

Page 8, line 1, insert after "No." *289,672*.

A reconsideration is requested.

Very respectfully, W. BAKEWELL & SONS,
Attorneys for W. R. Jones.

The foregoing amendment has been drawn to distinguish the claim from the references. As the references are simple and the purpose of the amendment apparent it seems to be unnecessary to accompany it with such detailed explanation as a due regard to the convenience of the examiner ordinarily demands.

W. BAKEWELL & SONS.

1028 Room 149.

PITTSBURG, *December* 10, 1888.

The Commissioner of Patents.

SIR: We enclose herewith an amendment in the above-named application, which is an exact copy of an amendment dated December 8th, 1898. In the amendment dated the 8th inst., we omitted to send a supplemental oath, and we desire to have the amend-

[Matter enclosed between rules erased in copy.]

ment of the 8th inst. cancelled, and the one sent herewith substituted in place of it.

Very respectfully, W. BAKEWELL & SONS,
Attorneys for W. R. Jones.

Amendment of Dec. 10, 1868.

PITTSBURG, *December 10th*, 1888.

The Commissioner of Patents.

SIR: This case is amended as follows:

Claim 1, line 5, before "substantially," insert:

from which the bottom of said vessel or receptacle is downwardly inclined.

Cancel claim 3, and insert:

A.
Cancelled per "B," Jan'y 24, '89.

3. An apparatus for receiving and mixing successive charges of molten metal, previous to its further treatment or use, consisting in a covered vessel or receptacle provided with a discharge opening and mounted on permanent pivotal supports, and a power engine connected with the said vessel or receptacle for tilting the same; substantially as and for the purposes described.

1029 Cancel claim 4, and insert:

A¹.
Cancelled per "B," Jan'y 24, '89.

4. An apparatus for receiving and mixing successive charges of molten metal, previous to its further treatment or use, consisting in a covered tilting vessel or receptacle having a charging hole through which the molten metal is introduced, and a discharging hole or tap, and a stop which limits the tilting of said vessel or receptacle to prevent discharge of the entire contents when in use; substantially as and for the purposes described.

[Matter enclosed between rules erased in copy.]

Add the following claim:

A². Cancelled per "B," Jan'y 24, '89.	6. An apparatus for receiving and mixing successive charges of molten metal, previous to its further treatment or use, consisting in a covered refractory-lined vessel or receptacle having a discharge hole, and removable cover for the latter; substantially as and for the purposes described.

Page 7, line 17, cancel from beginning of this line to end of sentence on line 23 of page 7.

Page 8, line 1, insert after "No." *289,672.*

The foregoing amendment has been drawn to distinguish the claim from the references. As the references are simple and the purposes of the amendment apparent, it seems to be unnecessary to accompany it with such detailed explanation as a due regard to the convenience of the examiner ordinarily demands.

A reconsideration is reported.

Very respectfully, W. BAKEWELL & SONS,
Attorneys for William R. Jones.

STATE OF PENNSYLVANIA, } ss:
County of Allegheny, }

William R. Jones, whose application for letters patent for an improvement in apparatus for mixing molten metal (serial
1030 number 289,673) was filed in the United States Patent Office on or about the 31st day of October, 1888, being duly sworn, deposes and says that he verily believes himself to be the original and first inventor of the improvement as described and claimed in the foregoing amendment, in addition to that which was embraced in the claims originally made, and that he does not know and does not believe that the same was ever before known or used, and that the matter sought to be inserted formed a part of his original invention at the date of filing said application.

WILLIAM RICHARD JONES.

Sworn to and subscribed before me this 10th day of December, 1888.

W. B. CORWIN,
[SEAL.] *Notary Public.*

[Matter enclosed between rules erased in copy.]

Patent Office Letter of December 29, 1888.

This application has been reconsidered.

Claim 1 is met by U. S. patent No. 287,864, Ryder, Nov. 6, 1883 (puddling furnaces), and German patent No. 8099, Krupp, Sept. 17, 1878 (treating molten iron).

Claim 2 is met by U. S. patent No. 238,110 of record.

There is no combination in claim 3 between the power engine and the receptacle, and the claim is met by the references of record.

Claim 4 is met by U. S. patent No. 287,864, and German patent No. 8099, both cited above to claim 1.

Claim 5 is met in U. S. patent No. 208,561, Schulze-Berge & Barnstorff, Oct. 1, 1876, (treating molten iron, air, steam or gases).

Claim 6 is met by U. S. patents Nos. 381,119, Devereux, April 17, 1888, (reducing and separating) and 361,556, Bayliss, April 19, 1887, (converters).

F. P. MacLEAN,
Examiner, Division III.

1031 *Amendment of Jan. 29, 1889.*

To the Commissioner of Patents.

SIR: We desire to amend the specification & claims in the above case as follows:

Page 2, line 11, erase "more than one," and insert "*one or more.*"

Page 4, line 23 erase "trunnions," and substitute "*journals or bearings.*"

Page 5, line 1, erase "trunnions" & insert "*journals or bearings.*"

Page 6, line 3, erase "the hopper 5," and insert "*the discharge spout 6.*"

Page 6, line 3, erase "22" and insert "*operated by a weighted lever 16.*"

Page 6, at the end of line 4, insert "*a draft of air through the vessel and.*"

Page 6, lines 6 & 7, erase "when the mixer 2 is not being charged."

Page 6, line 13, erase "valve" & insert "*cover.*"

Page 7 & 8, erase lines 17 to &, including line 19 page 8.

Page 7, line 4, erase "but which do not form essential features thereof."

1032 Erase the claims as now presented and insert the following:

B. 1. An apparatus for receiving successive charges of molten metal from a blast furnace or furnaces, and mixing the same previous to further treatment, consisting of an iron vessel having a refracting and heat-retaining lining, and being of substantially rectangular and trapezoidal shape, in longitudinal cross-section, covered on top with a remarkable refractory-lined cover or covers, and furnished with suitable manhole or manholes, and having a charging hopper at or

near the top at one end and a discharge opening at the other end placed above the surface level of the fluid metal when the vessel is in its normal position; said vessel resting on a pivotal support or supports located nearer to the discharge end than the centre of gravity of the vessel, in combination with mechanism for rocking the vessel on its pivotal support substantially as and for the purpose hereinbefore described.

Insert C, April 26, '89.

W. BAKEWELL & SONS,
Attorneys for Applicant.

January 24, 1889.

1033 *Circular of Allowance.*

Serial No., 289,673.

DEPARTMENT OF THE INTERIOR,
U. S. PATENT OFFICE,
WASHINGTON, D. C., *Jan.* 26, 1889.

William R. Jones, care W. Bakewell & Sons, Pittsburgh, Pa.

SIR: Your application for a patent for improvement in apparatus for mixing molten pig metal, filed October 31, 1888, has been examined and allowed.

The final fee, twenty dollars, must be paid, and the letters patent bear date as of a day not later than six months from the time of this present notice of allowance.

If the final fee is not paid within that period the patent will be withheld, and your only relief will be by a renewal of the application, with additional fee, under the provisions of section 4897, Revised Statutes. The office aims to deliver patents upon the day of their date, and on which their term begins to run; but to do this properly applicants will be expected to pay their final fees at least twenty days prior to the conclusion of the six months allowed them by law. The printing, photolithographing, and engrossing of the several patent parts, preparatory to final signing and sealing, will consume the intervening time, and such work will not be done until after payment of the necessary fees.

When you send the final fee you will also send, distinctly and plainly written, the name of the inventor and title of invention as above given, date of allowance (which is the date of this circular), date of filing, and, if assigned, the names of the assignees.

[Printed across the face:] ☞ In remitting the final fee give the serial number at the head of this notice.

1034 If you desire to have the patent issue to assignees, an assignment containing a request to that effect, together with the fee for recording the same, must be filed in this office on or before the date of payment of final fee.

Additional copies of specifications and drawings will be charged

for at the following rates: Single copies, uncertified, 25 cents; 20 copies or more, 10 cents each. The money should accompany the order.

Very respectfully, BENTON J. HALL,
Commissioner of Patents.

The within title is that given by the examiner in charge, as most appropriate to your invention. Should you desire a change in the same, satisfactory reasons must be given therefor on or before the payment of the final fee.

Amendment of April 23, 1889.

PITTSBURG, *April* 23, 1889.

The Commissioner of Patents.

SIR: In the prosecution of the companion application to this case, relating to process of mixing molten metal, it has seemed to us that the claim at present in this application does not adequately set forth applicant's invention, and we therefore beg leave to amend by adding the following claim:

2. A mixing vessel for molten metal, said vessel having a refractory lining, a heat-retaining cover, a charging opening, and a discharging opening or spout, and provided with a pivotal support arranged forward of the centre of gravity of the vessel, whereby the floor of the said vessel will normally incline downwardly
1035 from the discharge opening or spout towards the rear of the vessel; in combination with power mechanism for rocking the vessel on its pivotal support; substantially as and for the purposes described.

Very respectfully, W. BAKEWELL & SONS,
Attorneys for W. R. Jones.

Memorandum of Fee Paid at U. S. Patent Office.

Amount received, $20. Chief clerk. Serial No., 289,673; 18—. Inventor, William R. Jones. Patent to be issued to inventor. Name of invention, as allowed, apparatus for mixing molten pig metal. Date of payment, ——. Fee, final fee, $20. Date of filing, ——. Date of circular of allowance, January 26, 1889. The Commissioner of Patents will please apply the accompanying fee as indicated above.

W. BAKEWELL & SONS, *Attorneys.*

Send patent to W. Bakewell & Sons, Pittsburg, Pa.

July 26, '89.

Examiner's Book, 40571.

(Serial No., 289,673); patent No. 404,415, div. 3.

William R. Jones,
Of Braddock,
County of Allegheny,

State of Pennsylvania.
Invention, apparatus for mixing molten pig metal.

Parts of application filed.
- Petition, Oct. 31, 1888.
- Affidavit, " " "
- Specification, " " "
- Draw'g, 2 sh'ts, " " "
- Model not required.
- Specimen, none.
- First fee, cash, $15, Oct. 31, 1888.
- " cert., ——.

1036 App. filed complete Oct. 31, 1888.
Acklgd. Nov. 2, '88.
Examined Jan. 25th, 1889. F. P. Maclean, ex. div. 3.
Countersigned, W. B. Burke, Jan. 25, '89, for Commissioner.
Notice of allowance, Jan. 26th, 1889.
Final fee, cash, $20, May 11, 1889.
" " cert., ——, 188–.
Patented June 4, 1889.
Att'y or P. O. address, W. Bakewell & Sons, Pittsburg, Pa.

1888.

Contents.

Application, — papers.
1. Dec. 1, '88, letter.
2. Dec. 12, '88, am'd'ts "A A" and oath.
3. Dec. 29, '88, letter.
4. Jan. 24, '89, am'd't "B."
5. Ap'l 26, '89, am'd't "C."

Metallurgy: Converters.
Title: Improvement in apparatus for mixing molten pig metal.

1037 *Iron and Steel Manufacture.*

By F. Kohn, London, 1868.

Page 74.

The History of the Bessemer Process.

From a paper read by Mr. Henry Bessemer before the British Association on September 8, 1865.

On the 13th of August, 1856, the author had the honor of reading a paper before the mechanical section of the British Association at Cheltenham.

It may be remembered that an important part of the process, as described at Cheltenham in 1856, consisted in tapping the fluid crude iron from the blast furnace and allowing it to flow direct into the converting vessel, and be there blown to the extent only of decarbonizing it so far as to produce cast steel. This part of the original programme has been most successfully carried out in Sweden,

where an extensive establishment for its manufacture has been erected by M. Goranson, of Geffle. The large steel circular saw plate exhibited is an example of the conversion of crude cast iron run direct from the blast furnace into the converting vessel, and there blown for nine minutes, in which period it had been converted into cast steel of the desired quality, and was then poured into an ingot mould without being recarbonized, and wholly without the employment of spiegeleisen or manganese in any form whatever.

With this illustration of the capabilities of the process as originally described at Cheltenham, the author will proceed to show how the disadvantages of the old fixed converting vessels were remedied and other improvements introduced. Many forms of converting vessels were tried on the large scale before this desirable object was attained. In some of them the lining was too easily broken down by the violent motion of so heavy a fluid as iron. In some of the forms tried, the angles allowed the metal to solidify in
1038 them, and so clog up the vessel; in others, the mouth of the vessel being too small, caused the metal to be thrown out by the force of the escaping blast. It was also found that if the mouth was too large the heat escaped, so as to cause part of the converted metal to solidify in the vessel; the relative height and diameter of the vessel was also found to produce important differences in the working of the process; finally, and after many long and expensive trials, the form of vessel now exhibited was adopted. This vessel is made in two parts, so as to admit easily of its being lined up with a pulverized silicious stone, known as "gannister," which so resists the action of the heat and slags as to last for fully 100 consecutive charges of steel before it is worn out. Its form is that of the arch in every position, which prevents the lining from falling down by its own weight. There are no angles in which the splashes of metal can solidify and accumulate. Its mouth directs the flame and sparks away from the workman, and from the moulds and other apparatus; while the throat of the vessel and the position of the mouth almost entirely prevent the throwing out of the metal. The vessel is mounted on trunnions supported on stout pedestals, so that a semi-rotary motion may be communicated to it at pleasure. The tuyeres are placed at the bottom of the vessel, so as to force the air vertically upward through the metal, as shown, without coming in contact with the sides of the vessel. When the crude metal is to be run into the vessel it is turned on its axis nearly into a horizontal position, the mouth being a little higher up; a gutter will then conduct the crude cast iron from the melting furnace into it. It is not necessary to turn on the blast until the whole of the metal is run in, because the tuyeres occupy a position above the level of it. As soon as the air is admitted through the tuyeres the vessel is turned into a vertical position, when decarbonization immediately commences. As soon as this is effected as much molten pig iron made from spathose iron ore is added to it as will restore
1039 the quantity of carbon necessary to produce the desired quality of steel, which is then run into the casting ladle in the manner shown, and from whence it is transferred to a series of

iron moulds ranged in a semicircular pit, each mold being placed within the sweep of the casting crane; the filling of these molds is regulated by a cone valve made of fireclay and fitted in the bottom of the casting ladle, so as to be opened or shut at pleasure by means of a handle on the outside of the ladle.

It will be readily understood that, in the fixed vessel first described, any giving way of a fireclay tuyere would stop the process and cause much inconvenience. But with the movable vessel it is not so, for at any moment of time during the process the vessel may be turned on its axis and the tuyeres raised above the level of the metal; the blast may then be turned off, the tuyere box opened, and the faulty tuyere stopped up or removed, after which the process may be again resumed. The movement of the vessel on its axis, the rise and fall of the casting crane, and the other cranes employed for removing ingots from the casting pit, are all effected by a simple hydraulic apparatus, so that the whole process is under the perfect control of a single operator, placed far away from the heat and showers of spashes that accompany the process.

1040 *Iron and Steel Manufacture.*

By John F. Kohn, London, 1868.

Page 91.

The Barrow hematite steel works.

The pig iron is melted in Clayton's patent furnaces, four of which are arranged behind each pair of converters. There is occasionally a quantity of Swedish pig iron added to the charge, and the usual application of spiegeleisen is, of course, made besides. The converters in the adjoining shed are differently arranged. They form two groups of three vessels each. These converters are constructed for charges of 7 tons; they are 12 feet 10 inches in diameter outside, and 11 feet clear diameter inside. Their total height is about 15 feet. The hydraulic rams and racks for tipping the vessels are placed in a vertical position in order to gain space, and the three converters turn against the centre of the circular casting pit, which is 30 feet in diameter, so that all can pour their contents into one ladle if required. The space behind the three converters is surrounded by an elaborate platform upon which some melting furnaces are placed, but it is intended to work these converters with liquid iron from the blast furnace direct. For this purpose a ladle capable of holding 10 tons of molten pig iron has been mounted upon an iron truck in a frame, which permits the ladle to be lifted off the truck by a crane and then tipped, so as to pour out its contents. This ladle is filled at the blast furnace, and then taken to the converters upon the rails which connect the furnaces and steel works. Some trials which have been made have proved successful. The iron remains perfectly liquid during the short time required for the transport, and the charge can be converted without difficulty.

1041 *Iron and Steel Manufacture.*

By F. Kohn, London, 1868.

Page 95.

The Neuberg iron and steel works.

The Neuberg works contain two blast furnaces, each 45 feet high and 8½ feet at the boshes; they are closed at the top and worked with hot blast. Each furnace has its own blowing engine, hot-blast stoves and steam boilers, so as to work independent of the other, but the arrangement at both furnaces is symetrical. The hot-blast stoves and the boilers are placed at a height of 31 feet above the pig beds, and carried partly by the outer masonry of the furnaces and partly by the solid ground behind the latter, the furnaces being placed at the side of a hill, which has been transformed into a series of terraces for this purpose. The highest terrace is level with the blast-furnace tops, and it affords ample space for storing the raw materials and charging the furnaces. Close to the furnaces is placed a new building, which contains a Bessemer steel apparatus consisting of two 3-ton converters. This is the plant with which the excellent specimens of steel exhibited at Paris were produced, and it is generally considered to be the most successful Bessemer steel works in the world, so far as the quality of the product is concerned. It is less successful with regard to economical working and commercial results, but, as a whole, it is a tolerably well arranged set of Bessemer steel converters. The converters are of somewhat smaller diameter and of comparatively greater height than the 3-ton converters usually made in England; the throats especially are very narrow, and may in all probability cause an undue amount of back pressure upon the blast by throttling the exit of the gaseous products of combustion.

The two vessels are placed so as to tip against the center of the casting pit when turned down, an arrangement which involves a waste of space and some inconvenience in the construction of the runners for charging the converters with the molten pig iron.

1042 The pig iron is run from the blast furnaces direct into the converters. For this purpose a ladle mounted upon a track is employed which is filled at the blast furnace, and then run upon rails through a distance of a few yards only to the converter. When arrived in front of the charging gutter the ladle is tipped over and discharges the iron into the latter slowly and steadily, so as to let it run into the converter in a continuous stream.

The charge is then carried on in the usual manner, only during the first stage of the process a peculiar innovation has been carried out by M. Stocker, the manager of these works. M. Stocker blows a considerable quantity of charcoal powder through the liquid iron along with the blast. This is done at regular intervals during the first period of the process before the white flame makes its appearance at the mouth of the converter, and is done for the purpose of heating the charge by the combustion of the charcoal within the

vessel. This is said to be particularly effective when "white iron" or iron containing a small percentage of carbon, is worked in the converter. The supply of additional heat to the charge during the period of desilicatization maintains the mass in a state of sufficient fluidity until the combustion of carbon contained in the iron itself is so far advanced as to require no further supply of heat. The spectroscope has been tried at Neuberg by Professor Liellegg, but the results have not been favorable, at least, the employment of the spectroscope has not been introduced for practical purposes. The final addition of spiegeleisen is replaced by a small quantity of liquid iron from the same blast furnace from which the whole charge is drawn. The converter is turned up, and the blast is sent through the charge after this addition—a practice which has not been found advantageous in English Bessemer steel works, but which is said to cause no inconvenience at the Neuberg works.

1043 *The Journal of the Iron & Steel Institute.*

Nos. I–II, 1871.

Mr. Kohn, in reply to the remarks made by the various speakers, referred to the method in which the steel at Terre Noire is run direct from the blast furnace into the Bessemer converter. The iron is first run into a ladle, as explained by Mr. Menelaus, and so taken to the converter. The ladle is brought to the back of one furnace, and half filled; it is then run to the next furnace and filled up. In this way the Terre Noire Co. always obtain a mixture of the metals, and therefore the greatest regularity is secured through the rest of the work. The furnaces are kept in regular working order, and by carefully managing the charges of the blast furnaces, and watching them as much as possible, the practical result is that there is no inconvenience as regards the furnaces themselves in tapping frequently. The same thing is done at Mr. Schneider's place at Creuzot, but he believed they do not there go so far as to mix the iron. The only difference at Creuzot is that there is a considerable distance between the converters and the blast furnaces, and they use a truck similar to one which some years ago was constructed at Barrow, and intended for bringing the charge to the Bessemer converter. In large furnaces the inconvenience of tapping frequently would be very great, except where a great many converters were working at the same time, in which case the charges could be so worked as to commence several at the same time. There would be no inconvenience by this method. The only other place where he had known iron worked direct from the furnace into the converter is in Styria, at a charcoal furnace. He had worked one in Styria, but there the furnaces are so small that it is quite enough to tap one furnace to fill one converter. Therefore, the inconvenience does not arise there. With regard to the remarks which Mr. Bell had made, he must correct an error into which he (Mr. B.)
1044 had fallen. The author of the paper did not advance any theory; on the contrary, he only alluded to the difference

that exists in the opinions of metallurgists on certain points, and to the fact that he was endeavoring, by means of analyses of steel which he was making, to arrive at some facts which might lead to the acceptance of a theory. It certainly was necessary to form something like an opinion to know in what direction to go with experiments. It would not do to make experiments blindly; therefore, with all due deference to Mr. Bell, he submitted that it is necessary to form an idea with reference to a theory, and then to follow it out by experiments to see if it will prove correct, and that it is not desirable to proceed with investigations in the dark.

1045 *The Journal of the Iron & Steel Institute.*

London, volume 1, 1874.

Pages 348 to 367, inclusive.

THURSDAY, *3rd September*, 1874.

The president commenced the proceedings by asking Mr. Holley to read his paper on "Rolling-mill machinery arrangements in America," which was as follows:

American Rolling Mills.

By Mr. Alex. L. Holley, New York.

The object of this paper is to describe the general arrangement of American steel-rail mills of recent type, and some of the more important details of their machinery and practice, rather than to bring forward any remarkable novelty.

As most American works have but one pair of 5 ton converters each, and make but 150 tons per day, the rail mills are kept full by rolling steel rails for two or three weeks, and then iron rails for one or two weeks. The regular capacity of the average American 3-high train may be put down at 200 tons per 24 hours, of 60 to 65 lb. rails 30 feet long, although most of the mills have too few reheating furnaces for so large a product. The Scranton mill for some time averaged 440 iron rails in one turn, out of 11 ordinary reheating furnaces, or at the rate of some 225 tons per day. The Superior mill, at Pittsburgh, and the Danville mill have average 360 iron rails per turn out of 10 and 12 furnaces respectively. The Cambria mill and the Troy mill have frequently made 330 to 340 steel rails per turn, out of 9 furnaces, which is 180 to 190 tons per day, or from 1,000 to 1,040 tons per week of 11 turns, or 5½ days.

A 6½ to 7 inch bloom is rolled into a 60 to 65 lb. rail in 13 to 15 passes; the rolling occupies 1½ to 1¾ minutes. The speed of 21 to 24 inch trains is from 70 to 80 revolutions per minute. The
1046 engine (direct) is, for steel, the equivalent of 46 in. by 4 ft., carrying steam at 70 lbs., and having a 56-ton fly-wheel.

The fuel employed in gas furnaces does not exceed 400 lbs. per ton of product for each reheat; the steam coal varies greatly with the character of engines, and averages some 600 lbs. per ton of rails for

all rolling mill purposes. The greatest economy of the gas furnace lies in the saving of oxidation. Careful experiments at the Union iron works, Pittsburgh, show its saving to be 5 per cent. in heating iron beam piles, as compared with the coal furnace. A year's practice at the Washburn and Moen Manufacturing Company's works, at Worcester, gave 2.53 per cent. waste on 1¼-in. iron; wire billets, against an average of 7 per cent. with the coal furnace and at the same works, a week's run has been made with 1.34 per cent. oxidation. The saving of steel is, of course, less than that of iron, because the temperatures are lower.

The future improvements most required, would appear to be labor-saving machines to handle the work at the rail rolls. A better rail-straightening machine is also very much needed. The limit of production for a single train seems to have been practically reached at 200 tons, or over 4 miles of bars per day; improved quality and machine-handling are now the problems that first require solution.

The president was sure the meeting would be very glad to hear the experience of English steel-rail makers, in order that it might be compared with the account which they had just heard from Mr. Holley. He thought Mr. Williams could, perhaps, give them some information.

Mr. Edward Williams remarked that the quantity of steel produced by an American converter, within a given time, appeared to be greatly in excess of the best makes he had ever known in this country; but he saw no reason to doubt the correctness of the figures. He asked Mr. Holley whether, within his knowledge, it had occurred to the American makers to roll steel rails as tyres, and so
1047 save crops. He (Mr. Williams) believed it quite possible to do this, and thought it would not be difficult to cast the ingot rings to weight. To roll a circle of say 24 feet diameter, seemed to him not very difficult, and to cut it open and straighten out the rail afterwards, would probably be simple operation. He need not say that to save the rail crops would be a very considerable economy.

Mr. Holley described a continuous stream of ingots passing through the heating furnace, not charged in heats and rounds as was customary in this country, but in steady flow from the pit through the furnace to the rolls.

Mr. Williams presumed that this was only possible for first heating, and not for reheating blooms, which would have to be hot enough to roll into rails. Mr. Holley had indicated, as an improvement of the first necessity, the substitution of mechanical appliances for hand labour at the rolls in the rail mills. This, no doubt, was important; but Mr. Williams thought there was a possible economy of greater value, viz: to take the fluid pig iron direct from the blast furnace to the converters, and so save the present costly and, he believed, needless processes of casting into pigs and remelting. The cost of these was very considerable, and might, he was convinced, be altogether saved. Some of the Continental makers had commenced this system, which was at that time, Mr. Williams believed, in successful operation. To remelt the pig iron in a cupola, could

not improve it, and, probably, made it worse; and, at the works of Messrs. Bolckow, Vaughan & Co., it was proposed to try dealing with the fluid iron as described. So far as he could see, there was no reason to doubt the success of the operation; and he hoped to be able to report before long that it had succeeded. He asked Mr. Holley *whether the American* makers were adopting to any considerable extent the system of roll before roll, which seemed very well calculated for blooming ingots, and, perhaps, for roughing as well.

1048 For several years, piles of iron for rails had been bloomed in such rolls, upon the system patented by Mr. Charles White, which worked very successfully; and, as he had said, he believed steel could be very advantageously bloomed in a little way, saving the trouble and expense of reversing and lifting to three-high rolls.

Mr. Holley spoke of a system in the American rolling mills by which the rolls were brought down upon each other as required, and the bar operated upon passed several times through the same groove.

Mr. Williams thought this could only apply to very simple sections of iron and steel, and that for flange rails, or other sections requiring side work, it would not do. He would be glad to know whether he was correct in this.

Sir James Ramsden said, with reference to Mr. Williams' remarks as to the proposal for running the fluid iron direct into the Bessemer converter, the subject had been under the consideration of the Barrow Company for some time; in fact they had tried some practical experiments, and arrived at the conclusion as far as their knowledge went, it was a very doubtful undertaking. Certainly they could not produce the quality of steel that was necessary to satisfy the market at that time. In making the best class of steel rails, those who were conversant with the trade would be aware that it was necessary to have certain mixtures of iron, and it was a very curious fact that the iron, run on one day as pig iron, if sent to the converter on the next, would not make the same quality of steel as if that iron were to lie in the yard for three or four weeks. He (Sir James) was not able to explain the reason of this, but such was the fact. With reference to rolling the rails in a circular form, and then sawing them through so as to save the waste or crop ends, that was a question which the Barrow Company had also considered, and tested to a certain extent. They rolled hoops now of a certain diameter, and those who had visited the works on the previous day, would probably have noticed the hoop that was then being rolled. The

1049 intention was to cut it and use it for certain purposes, but they thought from their experience that the best mode of reducing the waste of crop ends, was that of rolling the long lengths, and, as they would have observed at the works, the company were rolling three rails in one length, and then sawing it, thus having two crop ends for three rails in place of the old system of two crop ends for one rail. The same subject had engaged the attention of Sir Joseph Whitworth, who proposed thus to make

plates, by rolling them in barrels and then sawing them through in various places according to size of the plate required. He should be very glad to follow Mr. Williams if he was able to show them that he could use the fluid pig iron direct in the Bessemer converter; there was no doubt it would be an enormous saving and economy, not only from the direct process itself, but in the alterations it would effect in the detailed departments.

Mr. Schneider remarked in reference to Mr. Williams' idea of running the fluid iron direct from the furnace, that there was one most fatal objection to it, *i. e.*, it was utterly impossible, when the iron was in the furnace, to know what its quality was. The whole reputation of the Barrow steel works consisted in the quality of its manufacture. It was not known and had never yet been found that they could have, even the whole of one cast of the same quality, and if they were to go on from day to day, running in the molten metal, the result would be that they would have accidents with steel rails in the same way that they had accidents with iron rails; the fact was that the steel rails would then be absolutely valueless. The real secret of success in making steel was this, that they must have the pile of pigs brought out, cast broadcast, placed in a long row, and uniformity of quality would be ensured, every single pig being tested before being put in the pile, by breaking it and ascertaining the quality, then taking uniformly—along the whole length of a long pile, extending perhaps a hundred yards—a pig here and there, so that when they commenced to work upon that pile they might have the same quality (as nearly as it was possible to arrive at it) until they got to the end of the pile. In casting the pigs, there was a certain amount of sand clinging to them, which the atmosphere removed, and thereby improved the quality. It certainly did happen, he could not distinctly tell why, that there was a better result from pigs exposed to the atmosphere for a length of time, than from those that were not, but the main point to which he (Mr. Schneider) wished to direct attention, was that they could not have uniformity unless they examined the iron as they put it in the pile, and they could only do that by casting the pig metal and then breaking it so that they might have thousands of tons of the same uniform quality, and then they could arrive at a satisfactory result and defy the examinations of all the railway inspectors in the world.

Mr. Williams was sorry to dissent from the confession of faith just made by Mr. Schneider. It was the good old orthodox belief, held for a long time firmly and explicitly by most people in the trade; but, of late, doubt had been cast upon it, and a great many iron and steel makers—himself among the number—had almost given it up. In his opinion, it had this defect, that it was not true. He denied that iron was necessarily improved by mixing with other iron. No doubt it was a rough and simple safeguard to mix several kinds of iron together, each of them bought as good of its kind. By such a system a fair average could be easily maintained, and it saved the trouble of watching and management; but, with moderate skill and reasonable attention, it was not difficult to work

very successfully with a single brand of iron. (Care being given to the charging and management of blast furnaces, it was easy to say before the iron was tapped what it would be, and only on very rare occasions, of which the furnace would give sufficient notice, would it be necessary to set the iron aside as unfit to be used alone. In truth he (Mr. Williams) had, for three or four years, been making steel very successfully—many thousands
1051 of tons—from pig iron produced from a single blast furnace, which scarcely or never varied so as to make difficulty.) The steel so made was, he felt sure, equal to anything produced in the best Bessemer works in England. He was afraid that no amount of care or expenditure of money would prevent entirely the breaking of a rail now and then. The great bulk of rails might be many times as strong as was necessary for any practical purpose, but now and then, at rare intervals, an almost worthless rail would find its way in. As was well known, a few rails broke in the process of rolling, either from accidental overheating, or for some other reason, and it would be readily understood that there came out sometimes a rail just a shade better than those which barely held together, and seemed whole like the rest, although, in reality, exceedingly weak and worthless. Under careful supervision, the number of such rails would be exceedingly small, but, in all probability, there would be some, despite everything. He was not able to assign a reason, and he scarcely liked to express the opinion, but he believed it was the fact that bad pig iron was improved by being kept in stock for a long time. Some chemical change probably took place, which he, not being a chemist, would not try to explain. In respect to saving crop ends, a great deal had been done, and done well at Barrow, where rails were being rolled in three lengths, thus saving two-thirds of the crops usually made. The tyre system, if it answered, would save crops altogether, or nearly so, and he hoped it would come into use.

Mr. E. Windsor Richards (of Ebbw Vale) said that, as regarded the question of making ingots direct from the blast furnace, it had gone far beyond the experimental process. At the Terre-Noire works, in the south of France, it was being done regularly; he had seen it in operation there himself. They had two blast furnaces placed nearly opposite the Bessemer works, and tapped 1½ tons from one furnace, and 1½ tons from the other into a ladle, which
1052 was conveyed to the Bessemer converter, and the fluid metal tipped in and blown in the ordinary manner, but it was very much better done at the works of Messrs. Petin-Gaudet, at Givors, near Lyons. This firm had two furnaces there, and the iron, at that place, being of such a regular quality there was not the slightest difficulty in making ingots of an even quality with metal direct from the blast furnace. The steel turned out at those works was well known, and bore a very high character for evenness of quality. He saw the process working about three years ago, and the operations were continued day and night. Further than that, the Belgians, at the works at Seraing, were so satisfied that this could be successfully done, that they were building new blast furnaces and

putting up a Bessemer plant to work in front of those furnaces, and to use the metal direct from them. He thought there was a very great deal of credit due the American gentlemen for the immense turn-out of ingots that they showed. He did not think in England, manufacturers, as a rule, did anything like it. He saw in the paper read by Mr. Holley, that 125 tons per day (he supposed that was a day of 24 hours) were made from a pair of 5-ton converters. As regarded the large quantity of rails they were turning out in America, he thought English makers approached more nearly to them than in making ingots. At their own mill, at Ebbw Vale, one pair of engines cogged a thousand tons of ingots, and rolled them into rails in one week; but the greatest credit was due to the Americans, in his opinion, for the immense product of ingots turned out of one pair of converters in a week.

Mr. Claridge wished to put it on record that running out the liquid metal into a puddling furnace had been done for more than twenty years in South Staffordshire. At the Chillington works, in South Staffordshire, the running out of the metal from the blast furnace had been done for that period, and he thought he was right in saying that it was being done at that date.

1053 Mr. Williams asked whether, since they had commenced doing that, they had built other puddling furnaces on the old system.

Mr. Claridge replied in the negative.

Mr. WILLIAMS: Any increase they have had to make they have continued to run into the same?

Mr. CLARIDGE: Just the same—ordinary hand-puddling furnaces.

A member remarked that it was now about thirty years since that plan was commenced; he was at the works at that time, and it had been done, not only at Chillington, but at other works besides these in the neighborhood of Bilston, by Messrs. Jones. It was now carried on, but he could not say that it was so prosperous and so satisfactory at any of the other works which had introduced it. He knows it was carried on at that time, and had been in operation at Chillington for quite thirty years. In reference to the question about pig iron improving by standing in the yard, all forge managers connected with puddling knew it was the fact. It might be attributed, in some respect, to loosing a quantity of the sand which was always detrimental when it existed in the puddling furnace. They had found that to be always the case; and where the principle of running into molds was adopted—although the iron might be quite as grey, or even more so, than that run into pig beds—it was always better.

Mr. Claridge could add one instance to those which had been mentioned in which the iron had been run from the blast furnace direct into the Bessemer converter—that was at some works in Sweden, where he had seen it done eight years ago. As regarded the other process, he thought at the next meeting he would be able to show the members (he had hoped it would have been ready to be substituted at that meeting) that it could be done at a very small

cost indeed with refuse coal instead of coke in the cupola furnace. Six tons of iron had been melted in it with 18½ cwt. of refuse
1054 coal. That was well authenticated; but the particulars of it, and the mode in which it was done, he was not then prepared to put before the meeting.

Mr. Snelus said he quite agreed with Mr. Williams that there was no insuperable difficulty in running the iron direct from the blast furnace into the converter, but he thought they ought to know the reasons why it had failed before, and what were the conditions that would ensure success. There were two: If the blast furnaces were working with a grey cinder they all knew well enough that the iron would come out grey; if they had good cinder in their blast furnaces the iron would be free from sulphur. That was the first essential that iron might come out with two per cent. of silicon, or even with one per cent., and it might contain five per cent. Now, those who were accustomed to the Bessemer process knew that if the silicon was below 2½ per cent., they would get a scull—the metal would not blow hot enough, and it would chill upon the sides of the ladle. On the other hand, if it had five per cent. of silicon, it would blow so hot that their molds and vessel linings would be all cut out. The only thing they wanted to do was to ensure regularity in the silicon after they had got their furnace working properly, and there was no very great difficulty in affecting this. If there was a black cinder on the furnace the iron was not suitable for the Bessemer process; but if there was a good grey cinder it might be taken for granted that it would make good steel. He saw no reason why the plan should not answer. He had advocated it for a long time, but it had been rather a radical change, and they were or had been, very conservative, and had not yet got to that stage. He saw no difficulty in taking two blast furnaces, and not only running the iron direct into the converter, but also ensuring regularity in the mixture. There was no great difficulty in ascertaining how much silicon there was in pig iron in half an hour. Most chemists would be able to do that, and when they knew
1055 it, it was *was* very easy to correct any excess by keeping a small stock of cold pig that was non-silicious. If the charge coming out of the two furnaces should, to any extent, be too silicious, it could be toned down; but the first essential was to get the metal sufficiently silicious to blow well, and by running it into a separate vessel, as they did in America, they could then deal with it as they liked. The plan in all the works in America was to melt in a cupola continuously, and then to run the iron into a ladle, which was balanced, and held from 10 to 12 tons. From that the six-ton charge was run direct into the converter. They wanted an intermediate vessel between the blast furnace and the converter and to ensure regularity in steel rails, they ought to know the amount of silicon contained in the metal before it was used. That could be regulated, and there was no very great difficulty in keeping it pretty nearly right in the blast furnace, as he (Mr. Snelus) knew from long experience. He was quite sure the iron would be better, and not worse, by being run direct from the blast

furnace. They would get a better rail by working with a low percentage of silicon than with a high one. The difficulty was that they were liable to make a scull. He was quite sure that if they could produce steel with one per cent. of silicon in it, and make a rail from that, it would give them the best result; if they worked with three or four per cent. of silicon, some of it often remained in the steel, and it was that which caused the steel to be brittle. Of course, he started with the assumption that the ores, coke and limestone used were free from phosphorus. With regard to the pigs improving by standing, he did not think there was any doubt that the benefit due to the removal of the same had been more felt in the puddling furnace than in the Bessemer process. In the puddling process, sand was, of course, very deleterious; it ran away with fettling, and prevented the iron refining so readily as it ought to do, thus wasting the metal; but in the Bessemer process that effect could not take place even if they melted the pigs
1056 in a cupola. He could not conceive any atmospheric action, consequent upon storing the pigs, which would improve them beyond the removal of the sand and the oxidation of the iron. He remembered that some time ago one of their American friends patented a process for removing phosphorus and sulphur from pig iron by dipping a solid red-hot pig into a bath of some chemical mixture; but he (Mr. Snelus) could not conceive any action by which the bath could permeate the solid pig in sufficient time to do any good, or to remove phosphorus or sulphur; neither could he see how the atmosphere could penetrate and produce any result in the pig. Further than that, analyses showed, as he had found on every occasion, there was no change whatever in the pig itself, however long it remained in stock.

Mr. J. T. Smith said he was at some disadvantage in entering upon the discussion, as he had been unable to arrive in time to hear the commencement; but it appeared to him that they were discussing what might as well be postponed, because they would, as far as he understood from Mr. Williams, have facts before them in a very short time, as Bolckow, Vaughan & Co. intended to remove their Bessemer plant from Manchester to their pig beds at Middlesbrough, and it would be better to hear, rather than to speculate upon the result. As they had entered upon the discussion, however, he might say he saw no reason whatever why the Bessemer process should not be conducted successfully by having the iron running direct from the blast furnace, provided they could have that amount of care in the selection of their ores, and in the working and filling of their furnace, which, he was bound to say, he did not at present see his way to obtain. Given that, they had that care and the proper material in the furnace, it was quite clear to his mind that no improvement took place in the actual remelting of the pig in the cupola—in fact, he should say, it was the reverse; and their present practice—of course recognizing that they had irregularities—knowing also that they
1057 could not always command the same classes of ore, and that it was impossible, they thought, to sufficiently distinguish

those classes to make an absolutely regular mixture—their principal at Barrow was, as they had seen on the previous day, to have long lines of broken pig iron, which were so arranged that in no one charge in the converter did they use more than 3 or 4 cwt. of any particular cast from any particular blast furnace; and they would be exceedingly glad if Mr. Williams would pioneer them out of that difficulty. If they could do it at Middlesbrough, they would, he hoped, be able to do it at Barrow; but he did not see how it was possible at Barrow unless they had a marvelous improvement, not only in their workmen, but in themselves; in fact, unless they imported some talent from Middlesbrough they did not see their way to carry out such an undoubtedly economical method. There was this peculiarity with respect to Bessemer steel, they could not really get bad steel into a finished marketable state; and it struck him (Mr. Smith) from the observations that he found his friend making, that he (Mr. Williams) must have had considerable experience with bad steel. He (the speaker) had heard a good deal about bad rails, and he recollected that in their own early days they used to have those things, but they did not see them now. He believed that this was simply because they adapted that peculiar method referred to—of mixing their pig iron before they put it into the cupola. He was very sorry that he had not heard Mr. Holley's paper; he had, however, read it with great interest, and he felt somewhat ashamed of the production that they obtained from each pit, as it was called, in their own establishment. The pits were that part of the Bessemer process where the converters were used; and he hoped that, as they had derived so much information from American gentlemen since the institute had been formed, many of them would carefully think over the observations that Mr. Holley had made; and he was quite sure that he (Mr. Holley) would find, so far as Barrow was
1058 concerned, that they would endeavor to see why they could not do as well with regard to quantity as they had done in the United States. Manufacturers in this country did not, perhaps, attach so much importance to increasing the quantity of steel produced by any particular converter any more than they did to getting beyond a certain point in the production of a blast furnace, unless they found that, by increasing the quantity, they secured increased economy; and that was one thing he had failed to see in the remarks that had been made with respect to the operations of the Bessemer process in America—whether, by the large production that they had from a given quantity of converters they had found that there had been any economy in the steel produced. He (Mr. Smith) was quite sure that if they were to increase their quantity of steel they would have to considerably modify the machinery, and the room in which it was worked; and it would have to be borne in mind, he believed, that, without exception, the machinery was designed and arranged by Mr. Bessemer and his partner in all cases in England, and that when they applied for royalties in the first instance, they were really bound to construct their works in a certain way. Some had modified the newer part of their establishments to some extent, but still they had kept very much to the old

design, and it appears to him (Mr. Smith) that they could not look forward to increasing the production of Bessemer steel from their converters without increasing the power of the machinery about them and the room, as well as the facilities for getting rid of the production.

Mr. W. Whitwell said there were one or two questions that he would like to put to Mr. Holley, through the chairman, and in doing that he would rather draw the attention of the meeting back to the excellent paper they had had from him. He thought if Mr. Holley would answer those questions it might lead them to some definite conclusion as to the reason why, in America, the products from a certain plant were so much greater than in this
1059 country. He (Mr. Whitwell) thought it was a very great point if they could, from a 5-ton converter, obtain—as Mr. Holley spoke of doing—from one-half to three-fourths more than they were getting in England, and he wished that Mr. Holley would tell them what, in his opinion, was the cause of this increased output. He (Mr. Whitwell) thought he had heard something said outside to the effect that, in the arrangement and in the fitting in of the tuyeres, there was some improvement, and he would like to know if there was anything in the position of the converters that enabled Mr. Holley to get the extra quantity.

He (Mr. Whitwell) quite endorsed the remarks made as to pig iron for iron manufacturing, but he did not certainly see that they applied so clearly in the case of the Bessemer process. He knew firms who were now storing their pigs, and who had done so for years, for two or three months, on purpose to have the sand rusted off, knowing that thereby they improved the quality without incurring any cost for improved mixtures.

In reference to making steel direct from the blast furnace, they had four or five different works on the continent which were already doing that; but he (Mr. Whitwell) had been particularly struck with one point, and that was the extreme care they used in mixing their ores, taking a certain exact weight and percentage of the most carefully selected quality of ores, and this enabled them to obtain that regularity from the furnace which was indispensable for the direct steel process. He imagined and believed that that was in a great degree the cause of the good results that Mr. Williams had obtained. He was sure they were much indebted to Mr. Holley for the paper, which proved that they had a great deal to learn in the arrangement of the mills; also in the construction and excellent finish which he had described to them so clearly.

1060 *Journal of the Iron and Steel Institute.*

London, 1875. Page 16.

The President's Address.

(Extracts from the above address delivered by the president, Mr. Menelaus.)

For the conversion of pig into wrought iron, the rotary puddling machine, in one or other of its form-, has occupied the attention of iron-makers for many years, and various attempts have been made from time to time to perfect the machine. When, under the auspices of this institute, the Danks machine was introduced into this country, success seemed certain; several machines were erected, mostly at and near Middlesborough, but they seem to have failed, chiefly from defects in mechanical construction. These defects have, I am told, been rectified, and several important improvements have been made in the construction and mode of working the machines. To Messrs. Hopkins, Gilkes and Co., is due the credit of having first introduced and practically tested these machines in England.

At our annual general meeting in May of last year, the Pernot furnace was described. This furnace is the revolving pan with the axis inclined, as invented by Maudsley; but M. Pernot has made an important improvement on Maudsley's furnace. He has mounted the revolving pan on a carriage on wheels, and it can be withdrawn from the puddling chambers for repairs.

Mr. Snelus, who has just returned from a tour through the French works, informs me that he saw three Pernot puddling furnaces at work at Messrs. Petin and Gaudet's works. They were working one ton charges of iron, mostly white, and each charge produced 18 cwts. of puddler bars.

The fuel was slack coal, of which they use 14 cwts. to the ton of puddled bars. The pans are fettled with Mokta iron ore, about 2½ cwts. being used to the ton of iron made. Each furnace pro-
1061 duces about 4 tons of puddled bars in 12 hours. Two puddlers at each furnace ball up the iron. Mr. Snelus adds that the furnaces have been employed some time, and that they seemed in fair working condition.

I think we may now fairly expect that mechanical puddling, in the hands of the many distinguished men who are now at work upon it, will soon be brought into successful operation; and further, I opine that it has been clearly demonstrated that the revolving puddling machine, of whatever type, if properly fettled and managed, produces far better results than does hand puddling. By this method, iron of very excellent quality can be made from pigs containing a large quantity of phosphorus, and I am of opinion that it is not unlikely that the puddling machine will very soon enable us to use largely some of the commoner qualities of pig iron for making steel.

In the manufacture of steel, we are making in England by the

Bessemer process alone, ten thousand tons per week, and the production is rapidly increasing.

Various mechanical improvements have been made, which enable us to turn out larger quantities. In some cases as much as one thousand tons per week has been made from a pair of converters.

The Americans have set an example in the many ingenious arrangements which they have introduced for getting a large amount of work out of a comparatively small plant. I believe that in this respect they stand at present unrivalled. In England we are following their lead, and we shall soon, I hope, be abreast of them.

When Mr. Bessemer first designed his steel-making plant, his idea was to run the iron direct from the blast furnace into the converters. His first apparatus, on a large scale, was erected at Dowlais, where it was put down in front of a blast furnace, and the iron was run direct from the furnace. The experiment, for reasons quite independent of the mode of charging the converter, was not successful; nevertheless, we in England have ever since been content for

1062 no sound reasons, I suppose, to melt down the pig iron at considerable cost, instead of running it straight from the furnace. In most cases in France, and in some other countries, the iron is run direct from the furnaces; and I see no reason why in England we should not revert to Mr. Bessemer's original plan, and so save all the cost and waste of melting. Of course, it will require careful management at the blast furnaces; but with our good fuel, excellent ores, and with a plentiful supply of pure foreign ores as a mixture, I see no difficulty in carrying out this economy in the production of Bessemer metal.

Mr. Bessemer informs me that, under his advice, in one of our leading steel works they are about to run the iron direct from the furnace; to use his own language, "They will use my process of further carburizing 20 tons of metal at a time in a hot vessel, mounted on wheels and running on rails to the converters; the metal will keep hot for several hours in this vessel. Less carburetted metal may be made in the blast furnace, and the necessary quantity of carbon added at almost no cost."

My friend, Mr. Edward Williams, is at present designing a large Bessemer steel works for his company (Bolckow, Vaughan & Co. Limited). He proposes to run the metal direct from the blast furnaces into the converters. I have no doubt that he will be successful, and that the economy will be very considerable. By treating the iron in this way, Bessemer steel will, in my opinion, be produced at a cheaper rate than wrought iron can be made from the same quality of pig iron, by the processes now in use.

I am speaking, of course, of the manufacture of Bessemer steel for ordinary purposes. Where a very special quality is required it may be necessary to select the pig iron, as we now do, and to remelt it; but this will be a matter of experience.

1063 Mr. Bessemer, as we have seen, has by his splendid invention, enabled us to produce a metal far superior in quality to wrought iron, and at a very moderate cost.

Extract from Discussion.

Mr. Lancaster replied, "America and all the rest." There was no doubt that the world was actively engaged in supplying itself with first-class iron and steel, and the determination of all countries to do that in the cheapest and most efficient manner possible was manifest wherever they might go. He remembered visiting a small works in Sweden soon after 1860, where he saw them casting out of one furnace directly into the Bessemer converter, and very successfully too it was done, by the charcoal system—the old charcoal furnace—but it did not give courage to gentlemen in this country to embark in the enterprise of casting direct from the furnace at that time. The French, on the other hand, boldly took it in hand as early as 1866, and had been prosecuting it from that time down to the present with the greatest success; indeed, he might say, there was now scarcely an establishment of any importance in France or in Belgium that was not casting directly, without remelting, from the blast furnace to the Bessemer converter. He scarcely need mention that if they stood aloof they would be beaten in the markets of the world; therefore, it was incumbent on the English manufacturers to exert themselves, and he was sure that the spirit of enterprise would very soon carry out that system of casting from the blast furnace

1064 *Journal of the Iron and Steel Institute.*

London, 1875. Page 125.

Manufacture of Steel.

Bessemer works.

By Sir I. Lothian Bell.

The very extensive application of the form of iron known as Bessemer steel renders it necessary, upon such an occasion as the present, to give some account of its manufacture.

The weight of steel made in America, according to the process which bears the name of our fellow-countrymen, was, for last year, estimated by Mr. Swank, the secretary of the Iron and Steel Association, to reach 175,000 tons, of which 135,000 tons were used for rails, and the remainder for a great variety of other purposes.

The two most interesting papers read by my friend, Mr. Alexander L. Holley, of New York, at our autumn meeting last year, gave us a very truthful account of the excellence of the more recently erected works, such as those I visited at Troy, Bethlehem and Joliet. It will be remembered by those who heard Mr. Holley, that by means of a duplicate bottom, when the tuyeres required renewing, a fresh set was very expeditiously placed in position. The convenience of this arrangement, added to the admirable manner in which the converters are situate in relation to the cupolas

and hydraulic cranes, enables the American steel-makers to get about one-half more work out of a pair of converters than is usually obtained in this country. The iron used is apparently easily "blown." I observed one "blow" finished in 13 minutes. The loss in the process amounts to from 14 to 16 per cent.

All, I think, that can be said of the blast-furnace process and the malleable iron works of America is, that they are keeping
1065 fairly up with ourselves, but in the Bessemer works it appears to me that for some superiority of arrangement and for some improvement in machinery over our own, we must look to the United States.

So far as I know, the Americans, like ourselves, have done nothing in imitating the French by running the iron from the blast furnace direct into the converter.

Journal of the Iron & Steel Institute.

London, 1875. Page 194.

The Manufacture of Bessemer Steel in Belgium.

By M. Julien Deby, C. E., Brussels.

The members of the Iron and Steel Institute of Great Britain were the first to promulgate the economic doctrine that it is more to the benefit of the manufacturer and of the trader in general to exchange freely the results of practice and of experience, than to lock up their proceedings from fellow-workers, and to live on hereditary secrets.

I am happy to have it in my power to affirm that this great idea, worthy of the century, is rapidly extending its beneficial influence beyond the contracted limits of the United Kingdom.

In America, Belgium, Germany, and even in France, most workshops of industry are now thrown open to the inspection of competitors, with a readiness which, a few years back, was quite unheard of.

As a slight proof of the truth of this assertion, I come before you this day with a full statement of what our Bessemer steel works in Belgium are now doing, and of how they are doing it.

M. E. Sadoine, the able director of the John Cockerill works at Seraing, at my request has given me full leave to divulge to the members of this institute the whole of the results obtained at his new works, without any restriction whatever as to what I may communicate.

1066 I shall, in consequence, proceed in as few words as possible to exhibit a condensed summary of the most important facts which I think may interest you.

At Seraing the iron is most successfully and regularly run direct from the blast furnace into the converters, a most economical process, which, to my knowledge, has not, as yet, been put into practice in Great Britain, but which I believe ought to become universal.

Belgium lays no claim whatever to originality in the matter of this direct process. As early as 1857 the Swedish works had used

it, and they continue to do so to this day, adding iron to the charge when the production of the furnace is insufficient. In 1863 the same process was introduced into the Styrian works, of Turrach, and in 1864 into those of Heft, in Carinthia.*

In 1864 the Neuberg Company in Styria applied it also, and this company, as well as that of Heft, have since that period considerably enlarged their works on the same basis.

In 1867 Terre Noire, in France, employed the direct run from the furnace, and, if I am not mistaken, the Creuzot has also lately adopted the same principle.

The new steel works, at Seraing, constitute one of the most important departments of that extensive establishment. Very few in Europe, if any, are better organized at the present time for the economical transformation of iron ore into steel on a large scale.

The whole plant was devised, and the plans put into execution by the combined efforts of two intelligent young engineers of the company, M. M. Greiner and Philippart, by whose kindness I have been able to examine minutely all details and to have access to official documents, from whence I have derived most of the figures contained in this paper.

1067 The foundation stone of the steel works of Seraing was laid in March, 1873, and on the 1st of February, 1874, the first blow was made in the Bessemer converters.

In order to simplify the subject, I shall proceed methodically—follow the ores in their successive transformation:

1. Into pig iron in the blast furnace.
2. Into steel ingots in the Bessemer converters.
3. Into rails, tyres, axles, &c., in the forge.

But, before doing so, I must give a short account of the plant and of its distribution.

When the whole works are completed, they will comprise four blast furnaces (of which two are already finished) united by bridges, and between which are placed steam lifts.

Each furnace is furnished with 4 Whitwell stoves placed in a square, forming thus two parallel rows of 8 stoves each.

The principal dimensions of the blast furnaces are as follows:

Diameter of hearth,	1.60 metres	= 5.248	feet.
" " bosh,	5 "	= 16.40	"
" " top,	3.50 "	= 11.48	"
Total height,	18.50 "	= 60.	"
Inclination of boshes,	$67\frac{1}{2}°$		
Capacity, 225 cubic metres = 7,942 cubic feet.			

Three blast engines of the special vertical type of Seraing, so well known on the continent, and of which 123 are now in operation in various places, furnish the necessary blast, at a pressure which attains 30 centimetres, or 12 inches of mercury.

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*These works were fully described as early as 1866 by M. Habets, of Liege, from official documents in the *Revue Universelle des Mines*, vol. 20, p. 273, where the advantages of the process were enumerated.

The blowing cylinders of the engines have a diameter of 3 metres, or 10 feet, and a stroke of 2.44 metres, or 8 feet. The steam cylinders are on the Wolf condenser principle.

The normal number of revolutions of the engines is 13 per minute. This furnishes 400 cubic metres, or 14,120 cubic feet of blast, the quantity needed for the combustion of 120 metric tons of coke in 24 hours.

1068 To the right and left of the blowing engines are situated the mixing sheds for ore, and outside of these again are the pumping engines for the whole of the hydraulic apparatus of the establishment.

The sheds, where the charges of ore are prepared, are supplied with hydraulic lifts, which raise the ore to the proper height, and allow of its being thrown into separate boxes or compartments, where a thorough mixture of raw material can be easily effected.

In front, and to the north, is placed a group of boilers made from Bessemer steel plate, 1.60 metres, or 5.248 feet in diameter, and 15 metres, or 49 feet in length. They each carry a large reheater 3.28 feet in diameter, and 49 feet in length. The boilers are heated by the escaped gases from the blast furnaces.

On the south side, the blast furnaces are situated alongside the Bessemer foundry, which is divided into three separate compartments by a series of cast-iron columns.

The first compartment comprises the pig bed, and also receives the ladles and the hydraulic lifts, which carry the molten metal from the furnaces to the converters.

The second compartment contains the cupolas, where the resmelting of the pig iron is effected when at any time or from any cause it is thought advisable to work by the old process.

The third compartment comprises the converter department. Here we find six converters, two to each pit, receiving alternately the iron from the furnace or from the cupolas, as the case may be, these last being furnished with hot-air receivers for keeping the liquid metal hot.

II.—*The Bessemer Foundry.*

The molten metal is, immediately it has run from the blast furnace into the tilt-ladle, taken to the converters by hydraulic lifts and the stationary bridge on which it is carried on rails. It
1069 is weighed in a very simple manner while on the lift, by means of the indications of an ordinary pressure gauge placed in communication with the water in the hydraulic cylinder of the lift.

No inconvenience is suffered if the iron left be for even 1½ hours in the ladle, beyond the presence of a small solid bottom, which can be remelted afterwards in one of the cupolas.

The whole operation of conversion of iron into steel lasts from 15 to 22 minutes.

In the middle of the decarburation, from 10 to 25 per cent. of rail ends are added, the quantity varying according to the temperature of the bath.

The most remarkable fact connected with the whole process at Seraing is that no spiegel whatever is introduced into the converter at the end of the blow, it having been found that the iron contained sufficient manganese to render this addition quite useless.

The economy realized by the direct run from the blast furnace is easy to calculate. It consists in a reduction in the quantity of iron used, added to a saving in fuel,* and to a diminution in labor.

Since iron has been run from the new Seraing blast furnace, not a single case of black slag has occurred, which gives sufficient proof that the iron produced is fit for the manufacture of first-class steel.

A very remarkable fact, as yet quite unexplained, is the undeniable one, that the direct product of the blast furnace works better in the mill and gives much tougher steel than that obtained by the re-melting of the same iron in the cupola.

The chemical composition being identical, the steel from the direct process has stood the ordinary tests for rails and tyres much better than that which has been obtained from the cupolas.

1070 Mr. Snelus said Mr. Lancaster and himself had visited the works at Seraing only a fortnight previously, and he could bear testimony to the correctness of all that Mr. Deby had stated. While doing so, he thought it right (on behalf of himself, and through himself for others to whom that information had been so liberally given,) to thank Mons. Sadoine, the general manager of the works, also Messieurs Greiner and Philippart, the two gentlemen who had carried out the plans and perfected the system so well. He might mention that, in company with Mr. Lancaster, he had made a special tour through France and Belgium, for the purpose of seeing that part of the work. They visited Creusot, Terre Noire, St. Chamond, Givors (where the blast furnaces belonging to St. Chamond were situated), and Seraing, and they found the direct process at work in all these places. He did not see a single scull at one of them, and thought that fact spoke volumes. So far as he could judge, the steel made at all the works was very good. He had had no means of testing mechanically the steel made; he had only got a chemical analysis of one of the specimens brought back. That was for a special purpose. It was the so-called phosphoric steel of Terre Noire. That had nothing to do with the direct process, but he believed the steel made by the direct process was (as M. Deby had said and as they had found it at Seraing) quite equal to, if not better than, the steel produced by the old plan of melting in cupolas. Thus, he saw no reason why they should continue that operation. He (Mr. Snelus) made out from their own cost sheets that there was a saving of 10s. per ton, at least, upon the rails, to be made by avoiding that costly roundabout process, and was exceedingly glad to find that there were none of the difficulties met with in the actual operations which had been so often mentioned as drawbacks to the plan. The works at Seraing were certainly better con-

*The slag from ordinary cupola charges contains from 25 to 30 per cent. of iron; that from the direct process only 5 per cent., while the manganese reaches 25 per cent. The diminution in waste bears on the iron carried off both as oxide and in a granular state.

structed for that purpose than any of the others which he had seen, but they were not working on so large a scale yet
1071 at Seraing as at Creusot. At Creusot they had four very large furnaces working direct into the Bessemer converters, and they seemed to go ahead there without any stop or hindrance, and without any trouble. At Seraing, the company were doing it much more skilfully, because they had laid themselves out for that, and for that alone. They had only one furnace at work at the time of his visit, but a second was being blown in. As had been stated, they had been working several months with the one furnace and had never had a bad cast. Mons. Greiner told him they had never had a black slag. That showed the care and skill which they applied to their blast-furnace practice. He was afraid they could not say as much for their own skill in England, but he hoped they (the English) would come to that, and certainly they did not mean to be behind their competitors. He thought it beho-ved our countrymen to take a lesson out of their book. We had taken one from America, having adopted part of the system that had proven so successful in America, viz., Holley's bottom; and he must tell them now (having had a longer experience of it than he had when he mentioned the same thing at Barrow) that they were even more satisfied with the improvement that Mr. Holley had made than they were at that time. They had made 460 tons of steel in a week out of one vessel. That they could not have done without the assistance of Mr. Holley. Then, they wanted to take a lesson out of the books of their continental neighbors, and apply a little of their metallurgical skill, and he thought if they brought both to bear they would be able reduce the cost of steel to a very low point; it had at present come down to very nearly the cost of iron, and he firmly believed, as Mr. Menelaus had said, that it would not be very long before they could produce steel as cheaply, if not more cheaply, and better, than they could make iron. He had to thank M. Deby, to whom they were very much indebted, for giving them
1072 that information, and at the same time to repeat his thanks to the gentlemen who had supplied it to him.

Mr. Edward Williams was pleased to hear the good account of making steel from iron taken in a fluid state from the furnaces, instead of by the old processes of casting into beds and melting down in cupolas afterwards. At the Barrow meeting it was said, on the highest authority, that it could never succeed. The results obtained at Seraing were very much what he expected, and he believed the day was at hand when the direct process (as they might call it) would be universal, to the advantage of all concerned, and that without detriment to the quality of the rails produced, but on the contrary, he thought, with improvement of that quality. Their friends at Seraing seemed to be doing very well at their blast furnaces, better than, he thought, had been done in this country, the furnaces only 60 feet high, 16½ feet in the bosh, using iron ore with only 45 per cent. of iron, averaging 409 tons of pig per week. That was a result such as, he thought, had not been achieved in this country. The Middlesbrough district was considered behind no

other in respect to blast furnaces, and it would have to look to its reputation if makes so good could be got from furnaces of such small size; besides, if he understood the figures aright, the pig was produced by the consumption of 110 lbs. of coke for each 100 lbs. of iron made. He was convinced from his own experience that there would be no difficulty whatever, other than the diffi-ulty always experienced in a large business, owing to the mistakes and imperfect knowledge of all parties concerned, and the inevitable variations in the quality of the material used. Beyond these, he did not think they would have any great trouble in so managing their furnaces, as to make the continuous process steady and successful.

Mr. Hackney said he would ask Mr. Deby and Mr. Snelus a question upon one point. So far as he had been able to gather it
1073 seemed to him that, certainly in most of the places, and, he believed in all the works, as far as he knew, where the pig iron was taken liquid from the blast furnace to the converter, it was a pig iron containing manganese.

Mr. Snelus acknowledged that it was.

Mr. Riley thought that the reason why the Barrow iron works did not run the pig iron direct from the blast furnace was the want of uniformity in the composition of the pig. The ores used at Barrow were in general silicious and not so uniform in quality or so readily smelted as the Spanish and Alderian ores used by the Belgian ironmasters for the manufacture of Bessemer pig. The analysis of the ore given by the author of the paper would confirm this view. Manganese not being found to any appreciable amount in the English hematite was also advantageous.

Mr. Maynard said their American practice correspounded with what Mr. Cowper had said. There they melted from 9 to 9½ tons in their Bessemer cupolas. He was sorry that he had not the exact figures with him, but he thought Mr. Holley had brought that out at the Barrow meeting. Some gentleman might remember what he stated at that time, and he (Mr. Maynard) knew that in their travels in visiting Bessemer works in this country and also in Belgium, they found the American cupola practice was better than anything they had yet found in England. In America they worked continuously, and just as long as it was possible to keep the cupola running.

Mr. Henry Brodgen asked permission to go back to the Sunday question. It had not been suggested by any of the gentlemen who had spoken, and he himself had no experience of it, but it seemed that it would not be a very expensive matter to run the Saturday night to the Monday morning iron into the Siemens furnace, and the question he desired to suggest was whether it would be more costly to maintain the heat necessary to keep the iron in its proper state for making steel until the Monday work began, than to adopt the plan of putting the pig iron back into the furnace.

1074 The president said his impression was that instead of running the iron into the Siemens furnace, and keeping it hot—as Mr. Brodgen, without full consideration, he thought, had suggested—he would (with his present knowledge and opinions) take the Sunday iron and convert it into steel in a Siemens-Martin fur-

nace, using scrap with it. He had a high opinion of the Siemens process, and he believed that in the end that would be the most economical way of disposing of the iron made on Sunday, and of the rail ends.

Mr. Williams observed that, in regard to Sunday working, the president would make special exception in favor of the Siemens furnace, but in the North there would be the same objection to the Siemens as to any other furnace working on Sundays.

The president explained that he was alluding to Mr. Brodgen's suggestion for dealing with the iron by running it into a Siemens furnace and keeping it hot until they began working on Monday morning. Mr. Brodgen could not have given the matter full consideration, or he would have seen that his plan would be impracticable. The iron might in some cases be cold. The cheapest mode of dealing with the iron, he thought, would be to work it up by the Siemens-Martin process, putting up a sufficient number of furnaces for the purpose.

Mr. Cowper remarked that it would have to keep till Monday.

The president said the iron would be cast into pigs, as at present, and would be worked up in the course of the week with ore and scraps.

Mr. Markham thought that Mr. Williams had rather overrated the importance of stopping the blast furnace on a Sunday. The Staveley Company had seven which stopped every Sunday, and had done so ever since the works were started. He was aware that the stoppage was attended with much inconvenience and loss, but still they were able to produce 200 tons of iron in a small furnace
1075 without working on Sundays. He thought they were attaching more importance to it than it merited. In all steel works there were a certain number of cupolas employed to remelt the iron, and he could not see the slightest difficulty in dealing with the Sunday iron. If they could not stop their blast furnace let them run the iron into pigs, and remelt it in the cupola. The Sunday iron would form a small percentage of the total quantity of iron produced from the furnace weekly.

The president was afraid that Mr. Williams' point was not fully appreciated by all the thinkers. He was going in for the greatest possible economy in making Bessemer steel. He wanted to introduce a perfect system. No doubt, stopping the blast furnaces on a Sunday would get over the difficulty, but it was an expensive remedy. They had had 30 years' experience of stopping the blast furnace on Sunday at Dowlais, and one of the first acts of his management was to alter this, and a very considerable saving was effected. Stopping on Sunday meant lessening the output, and, at any rate, Mr. Williams wanted to deal with the iron made on Sunday in the most economical way—if not as economically as by running it into the Bessemer converter then in the next best method.

Mr. Snelus said there was one point he would mention which had never been adverted to. It had been spoken of in the paper, but passed over in the discussion; it was, that the iron made

direct from the blast furnace was generally a little hotter than that which was remelted, because the silicon was burnt out in remelting. The result was that they generally had an available excess of heat in the converter; and a natural consequence arising from the fact was, that they might venture to put some cold iron into the converter. That was done quite largely at some places, and at Creuzot very frequently up to 20 per cent.; in fact, he had been informed that on one occasion they actually put 50 per cent. of cold iron into the converter, and even then the "blow" was all right. He
1076 did not advocate it either to the extent of 20 or 50, as he did not believe it to be a good plan to get the metal hotter than a casting heat, and he thought the best results were obtained when it was just about the right temperature to cast soundly and well. If they had an excess of heat they had not the best heat, and if they had a deficiency they of course got a "scull," but the metal from the blast furnace certainly worked hotter than the same metal remelted in a cupola; therefore, they might deal with a portion of Sunday's pig iron by putting it into the converter.

Mr. Cowper asked if it was reheated.

Mr. Snelus replied that it was not.

Mr. Riley said he thought that was the reason why the Barrow iron works did not run the pig iron direct from the furnace.

Mr. Hackney said the point he had been about to mention came very close to what Mr. Reiley had said; it was that he believed it had not been from want of enterprise or of skill on the part of English steel-makers or English workman that they had hitherto invariably remelted the pig iron for the Bessemer process, and had not worked direct from the blast furnace. He believed (and he would ask M. Deby and Mr. Snelus whether he was correct or not) that English steel-makers, using the ordinary qualities of English Bessemer pig iron, would be under greater difficulties in working direct, than the steel-makers of Sweden, Belgium or Germany; and for this reason it was generally known that if pig iron contained about 2 or 3 per cent. of manganese or more, it never contained more than mere traces of sulphur, however *how* much sulphur there might be in the ore or in the fuel; whereas, if the ores were of such a nature as to produce a pig iron free, or nearly free, from manganese, then, whenever the blast furnace was out of order, making No. 2, No. 3, or No. 4, pig iron instead of No. 1, the proportion of sulphur in the metal increased regularly as it became less and less grey. Thus, if they took a series of
1077 samples of pig iron from the same furnace, smelting ores free from manganese—No. 1 B, No. 2, No. 3, No. 4, and white iron—they would find the sulphur increase, in each sample, as it came nearer to white iron; but, if the ores contained manganese, they would find very little more sulphur in the less grey qualities than in the silicious or most grey; so that while the maker in Belgium, Sweden, or Germany (who had to do with a pig iron *iron* containing manganese,) had only one difficulty to deal with in using pig iron direct from the blast furnace (that the metal would work sometimes hotter and sometimes cooler in the converter,) the English

steel-maker, who generally used a pig iron make with coke as fuel, and from ores that contained little manganese, would not only have that difficulty, but the further very serious one that whenever the blast furnace happened to make, from the same charges of ore and coke, No. 2 or No. 3 iron instead of No. 1, that iron would always contain very much more sulphur than the No. 1, and if No. 1 iron was just good enough to make steel the less grey iron would be too impure. He would like to ask M. Deby and Mr. Snelus whether it was not the case that in all works where the pig iron was run direct from the blast furnace to the converter it was a metal that contained manganese, and whether such metal was not worked direct from the blast furnace to the converter with much less risk of making bad steel than in the case of metal free from manganese, inasmuch as the sulphur difficulty had not to be contended with. Bessemer pig iron that contained 2 to 4 per cent. of manganese might be known, without actual analysis, by the fact that in blowing such pig iron there was no need to add spiegeleisen at the end of the blow, the steel produced contained in itself as much manganese as was needed to make it forgeable.

He (the president) had no doubt at all that they would be able, by a judicious mixture of foreign ores, to make a quality of
1078 iron from the blast furnace that would be perfectly uniform, and have all the qualities necessary to enable them to run it direct into the converter. It was but fair to the Barrow Company to say that they were very favorably placed in respect to their ore supply. He did not mean to say that it would be advisable for them to run direct into the blast furnace. He understood that the works were laid out for making the experiment; they probably had tried it, and found that it did not answer their purposes. But this was no reason why it would not suit works differently situated. When ores had to be purchased they had the power of selection; whereas Barrow, with its inexhaustible supply of cheap ore, might find it very much cheaper to melt the iron down than to run it direct from their blast furnace. The paper quite confirmed the opinion he had long ago entertained, an opinion he believed, shared by every intelligent steel-maker—that they ought, in England, to introduce, when practicable, the economies introduced on the continent, and unless they did so they would be left behind in the race. He (the president) thanked M. Deby, in the name of the institute, for the paper he had read, and for the way in which he had given information of what they were doing in Belgium. The Seraing establishment seemed to have been judiciously laid out, and the work they were doing was equal to, if not better than anything he had before heard of.

1079 *Journal of the Iron and Steel Institute.*

London, 1875.

Page 344.

American Bessemer works and rolling-mill plant.

The following details of the Edgar Thomson Company, Limited, situated at Braddocks, eleven miles east of Pittsburgh, U. S., on the main line of the Pennsylvania railroad, may be of interest as showing the modern arrangements of an American Bessemer steel works and rail mill, considered capable of turning out 200 tons of ingots, and 225 tons of rails if rolled in double lengths, or 200 tons if in single lengths, per day of 24 hours.

The total surface area of the entire works is about 106 acres, and besides being traversed by the Pennsylvania and the Baltimore & Ohio railroads, has a frontage of 3,300 feet on the Monongahela river.

Buildings.—At present there have been erected: Cupola-house, 107 feet long, 44 feet wide, and 46 feet high; converting-house, 129 feet long, 84 feet wide, and 30 feet high; blast engine-house, 54 feet long, 48 feet wide, and 36 feet high; boiler-house, 178 feet long, 48 feet wide, and 18 feet high; gas-generator house, 90 feet long, 46 feet wide, and 26 feet high; rail mill, 380 feet long, 100 feet wide, and 25 feet high, with a wing 100 feet long, 35 feet wide, and 17 feet high; office and shop buildings, 200 feet long, 60 feet wide, and 18 feet high; and coal and iron store, 40 feet long, 20 feet wide, and 10 feet high. All these buildings have iron roofs, and are constructed wholly of brick except the generator-house and rail mill, which have iron side columns with timber side framing.

The converting appliances comprise three cupolas each 40 feet high, and 5 feet internal diameter; two 12-ton cupola ladles upon scales; two 5-ton converters, fifteen feet high by six feet internal diameter; twelve crane ladles for casting; and a full supply of ingot moulds and flasks for bottom casting.

1080 *The Journal of the Iron and Steel Institute.*

London, 1876.

The use of molten iron direct from the blast furnace for Bessemer purposes.

Pages 12–42.

The president said the council had for some time had under its consideration whether some mode could not be devised of introducing interesting subjects to the institute in some more easy method than by the writing of a paper, and they had determined to make the experiment that day. Their friend, Mr. Smith, was going to tell them his experience on what was perhaps the most interesting sub-

ject that could be brought before them at that time—a subject that, until lately, had had very little attention paid to it in England. Mr. Smith would tell him how successful he had been in conveying molten iron direct from the blast furnaces to the Bessemer converters. When Mr. Bessemer first made experiments on a large scale, at Dowlais, he ran his iron direct from the furnace; the experiments were not successful, but taking the iron direct from the furnace had nothing to do with the failure. For certain reasons, which he believed would come out in the discussion, the plan had not been until lately adopted in England, although it was in general use on the continent. He would now ask Mr. Smith to give the meeting the result of his experience at Barrow.

Mr. J. T. Smith, of Barrow, then introduced the subject of the "Use of molten iron direct from the blast furnace." He said the subject as to the running of molten iron direct into the Bessemer converter from the blast furnace had twice before been raised. On the first occasion, at Barrow, some remarks were made by various gentlemen in the discussion (of which he unfortunately was one), which he thought would have been materially modified had they known more about the practice that even at that time was going on abroad, and in a largely developing industry like that of steel,
1081 as well as that of iron, he did not see why there should be any difficulty in stating that they had been laboring under errors, because, if they acknowledged improvements, it certainly carried the fact with it that they had been in error before. On the second occasion, the discussion arose upon an interesting paper with respect to the works at Seraing, and he was glad now to be able to testify to the value of the paper, as also to the courtesy with which upon two occasions he had been received at Seraing, when he had been there to watch the process. The discussion that had succeeded that paper, or a large portion of it, ended in enquiring what could be done with the pig iron between Saturday afternoon and Monday morning. He thought the impression must have been upon the minds of members that it was necessary to place the Bessemer converters in close contiguity to the blast furnace; but when he went abroad, and saw what they were doing there, he found that in no instance was the furnace nearer, perhaps than 40 yards, and in some cases it was at least 200 yards distant; but in those places where the 200 yards prevailed, the ladle was drawn by horses to a lift, and in all cases, even that of Seraing, which was the most perfect, the lift was used to raise the ladle containing the molten iron taken from the blast furnace to the platform from which the Bessemer converter had to be charged. In watching the time that this operation took, it appeared to him that there should be no difficulty in constructing the necessary rolling stock, even at works like theirs, where the blast furnaces and the steel works were separated by a main line of railway, and in consequence of having to cross that main line of railway to a convenient and safe point, it was necessary to convey the molten metal from one and a half to two miles. All the gentlemen there would readily believe that a couple of miles, or even five miles, when they had a locomotive before the

ladle carriage, was not of very much moment, especially, as he would assure them that really the extent of cooling, taking place within the first half hour of the iron being put into the ladle,
1082 was inconsiderable. There was no difficulty in erecting new works, so that the iron could be run into the ladle for the Bessemer converter, or into the pig bed at pleasure; but in their case, at Barrow, they had to make a railway cutting at the foot of the pig beds, and an incline at the end of the steel works, so that the locomotive drew the carriage containing the ladle from the pig beds, ran it over from 1½ to 2 miles, backed the ladle up to the converter, discharged it, and took the empty vessel back again, and that was done, when everything was prepared for it, in exactly half an hour. It had sometimes happened that the converter was not ready to receive the iron, or occasionally they were interrupted in crossing the railway, and they had regulated the times of the trains to be exactly one hour, and in exactly one hour their trains had, for the last six months, run night and day, each time taking two ladles with seven tons each in them, and consequently the cost of transit of the molten metal of a couple of miles (each engine representing something like the conveyance of a thousand tons a week), was not a very serious matter. In fact, they really conveyed the molten iron more economically than they formerly put the pig iron into wagons, and unloaded them again at the cupola. The result of the operation in the converter was, of course, a subject of great anxiety; when they brought the molten metal from the furnace to the converter, really the care and attention there was of secondary importance to that at the blast furnace, from which must be sent iron of exactly suitable quality for the Bessemer purpose, and indirectly, he considered that they had derived some very considerable advantage even in that way, because he was satisfied that they had their furnaces better managed since those operations took place than they ever had before; and it was not an idle boast when he could say that two of the furnaces that were assigned to supply the steel works with molten metal had never missed one single cast for the last six months, and having, of course, to take a much larger quan-
1083 tity across than was represented by two furnaces, he considered that their customers, who bought the rest of the pig iron they made, also had an advantage from the very great regularity of the mixture of the ores which had been necessitated in consequence of their using a large proportion of iron themselves, as everybody knew that to make steel from it economically it must be made with great care and regularity. The practical difficulties that they had to encounter had really been very small, and he often wondered why they were so skeptical, and that they had not begun the direct process very much sooner; thus we felt somewhat ashamed that, instead of being amongst those who were the first to introduce that system, they had really been unduly cautious, and were simply following the lead of their friends abroad. So far as the quality of the steel was concerned, he ventured to express an opinion that the steel was better, and, he thought, in making that substantive remark, most gentlemen who understood the melting of

iron would agree with him that by no possibility could iron be purified by being subjected to the action of coke in a cupola, and in fact they had found upon various occasions, on careful analysis of the steel, an amount of sulphur, which could not be accounted for by the quantity in the pig iron. With respect to the economy of the process, they were not in a position, except roughly, to estimate that there was such a saving in the production of steel as to make it worth while their continuing the arrangement. There were certain drawbacks in their case which, perhaps, would not exist to the same extent if the works had been originally designed for the purpose, because occasionally the iron was perhaps an hour standing after being run into the ladle; then the sculls were pretty considerable, but as a matter of fact, in starting the system last autumn, and having gone through a winter (and those who were privileged to live on the west coast knew what it had been), the entire amount of scull which their ladles had produced was
1084 something under two per cent., which, of course, had been broken up, remelted in the cupola and had gone in the old form into Bessemer steel. The carriages had been constructed to run at a considerable speed, but they were not yet perfect. Their present plan was to hang the ladle at one end of the carriage and balance the other end, which, of course, made a very large amount of weight altogether upon the carriage; besides, the wheel base being somewhat too short, there was a considerable oscillation, and on some few occasions, in crossing points, the ladle carriage had gone off the road, but in no case had they ever lost any iron in an accident of that kind. They were now constructing carriages to carry the ladle in the centre, and by a simple contrivance move it forward to the end of the carriage before emptying it into the converter. He was not sure whether he had said enough upon the subject.

The PRESIDENT: You cannot say too much, Mr. Smith.

Mr. Smith (continuing) said, possibly some gentlemen might make suggestions which would require explanation; he should be glad, at the end of the discussion, to give any further information in his power, but he might just say, there was no doubt that the iron worked very much hotter in the converters, the result being that all the scrap, except the heavy scrap in the ladle, was charged into the converters, besides which they could work up a large amount of the rough steel scrap and short rail ends and crops to an extent that they never could before.

Mr. E. Windsor Richards said it must be very gratifying to the members of the institution to find that the discussion upon the subject raised by Mr. Williams, at the Barrow meeting, should have been so soon brought to an issue. They were successful at Ebbw Vale in making Bessemer steel from molten metal taken direct from the blast furnaces. The steel works were placed about three-quarters of a mile from the blast furnaces, the railroads leading to them had very sharp curves and heavy gradients, and the only point
1085 on which he had any doubt was whether it was possible to take five or six tons of molten metal over such roads and over

such gradients without spilling and sculling. However, the experiment was very quickly tried, and the result was so satisfactory that they continued work until they got nearly 40 casts of 5 tons each cast without any trouble or difficulty whatever. Upon one occasion, they had some friends there looking at the process, and they wished to do almost better than they had done at any other time; but the converter was not ready to receive the metal, and it had to wait in the ladle for a whole hour before it could be tapped into the converter, but beyond the metal running a little thickly over the runner into the converter there was no loss, and they had a most successful blow. It was found that in tapping the blast furnaces that a sufficient quantity of curf and slag ran out and formed a kind of crust on the surface of the metal, and this crust prevented any metal sloping over the sides of the ladle even when run by the locomotive at the rate of 10 miles an hour down a gradient of 1 in 40. Mr. John Parry, who had the chemistry of the subject in hand, found that it was necessary in the ordinary way of melting—that was by second fusion—to have at least 2½ per cent. of silicon in the pig in order to get a warm blow and without scull. This was brought to his (Mr. Richards') mind by the remark of Mr. Smith, who said, that in working direct from the blast furnace the metal worked hotter. No doubt it worked hotter, owing to the presence of the silicon. In melting down in the cupola, a certain amount of silicon was got rid of, and a certain amount was necessary in order to obtain a warm blow. Mr. Parry found, by very careful attention to the blast furnace (and in working in this manner of course a much greater degree of attention was required in selecting the coke and ores and in the careful weighing of materials into the blast furnaces), that with from 2½ to 3 per cent. of silicon the yield from the pig iron, which was carefully weighed before it went into the 1086 converters, in ingots showed a loss of 16 per cent. or in other words, that it took 24 cwts. of pig iron to make a ton of ingots. By careful watching of the blast furnaces, they had some casts with the silicon as low as 1¾ per cent., and that was found sufficient to give them a good warm cast when working direct from the blast furnace, and the yields from pigs to ingots was found to be very much better, in fact, 2 or 3 per cent. better. He did not think he had anything further to state from their experiments at Ebbw Vale, but he was so satisfied with the results obtained there, that he was following in the footsteps of Mr. Edward Williams, who had commenced putting up a large Bessemer plant at Messrs. Bolckow, Vaughan & Co.'s works, at Eston, for carrying out that process to a very great extent. They were at that time engaged in building six blast furnaces and four sets of Bessemer converters, and he hoped to have the pleasure at some future date of giving them the result of their working.

The PRESIDENT: Perhaps you would say, Mr. Richards, after all the experiments you have had in following Mr. Williams' footsteps, who, I know, took a great deal of trouble to ascertain the best modes of carrying out this new process, what distance are you putting your

converters away from the blast furnaces; what arrangement have you between the blast furnaces and the converters.

Mr. Richards, in reply, said they had such a very splendid site for their steel works—a ploughed field, perfectly flat, and they could do just as they liked. They were putting the six blast furnaces in a row, the hearths being high enough to allow the molten metal to flow into a ladle, which would be mounted on a four-wheeled carriage; the railroad leading to the converting-house would be parallel with the blast furnaces; the ladle would be run along the road, and, to avoid turn-table, would pass round a curve and be taken quite close to the converters. The metal then would be lifted and
1087 poured into the converters, which latter would be fixed in the American fashion. He (Mr. Richards) would have no hesitation in saying that it could be taken 1½ or 2 miles if necessary, but, of course, he should prefer it as near as possible.

The president said he believed Mr. Snelus had had some experience in that mode of dealing with iron.

Mr. Snelus said he might say they had been working at the direct casting from the blast furnaces for some time. Like Mr. Smith, when they first started, they had a little trouble with their carriages, but for the previous two or three weeks they had been working continuously. He might state to begin with, that they had only one pit at work, therefore they were limited as to the quantity they could make, and they had only three blast furnaces, the make of which was not very large. The previous week, they used 450 tons pig iron direct, and the result, which he had carefully watched, gave them a yield of 83½ per cent. of ingots, and 2¼ per cent. of scrap, including the ladle sculls. The ladle sculls were kept and weighed up; he did not think in any case they exceeded 15 cwt.

The PRESIDENT: Is that scrap of iron and steel?

Mr. Snelus replied, no; it was scrap of iron. He was speaking now entirely of the iron scrap. They had about 2¼ per cent. of iron scrap of all kinds, about half of it being ladle sculls, and the other half the raking out of the ladles and cleaning it for the next cast. That ladle scull might be easily broken up, and, as he said, in no case did the scull exceed about 15 cwt. There was just a thin scull round the ladle when it was raked out. They had one ladle to go 38 casts, 6-ton charges, without relining, and they had to run the ladle about 700 yards round a very awkward road. It was placed on a hydraulic lift, which at the same time lifted the ladle carriage and turned it round ready for running into the vessel. He had arranged the hydraulic casing with a spiral, and the ram was a curved wedge, and while the ram lifted the ladle, it also
1088 turned it round, and delivered it into the right position for tipping; but he was now engaged in making a better road to the converters. It would be almost a straight track from their blast furnaces, and they would take the ladle right up to the vessels, between the two vessels, and with the new carriage so arranged, the ladle would be in the center of the carriage. It would require no balance weight; the ladle would tip the metal and pour it

direct into the converter. They proposed doing away with runners altogether, for, with the necessity of making them, there was a loss incurred, in the scrap they would make, and also considerable trouble; by that means they would improve their present apparatus a good deal. He was satisfied with their present appliances, and it was very gratifying to him, as one of those who had advocated that method as strongly as anybody, to find that the thing was now so thoroughly successful. At the same time, he agreed with Mr. Richards that it was necessary to watch the amount of silicon in their iron, and not let it run so high as they used to do, because he believed with him (Mr. Richards), that an excess of silicon caused a great waste of iron. In his case, the previous week, they got the yield with no difficulty of working, and, in fact, no difficulty whatever. There was no cold heat at all, yet they had only got a yield of 24 cwt. to the ton; whereas, in working with the cupolas (where there ought to be a greater loss) they regularly worked with 23¼ cwt. to the ton, and he could only account for that difference from the fact that they had rather more silicon in the metal when they blew it, taking it direct from the furnaces, than they had when they remelted it in the cupola, and knowing that fact, it was not very difficult, he thought, to counteract it, and reduce the silicon in the blast furnace. Of course, he agreed with all that had been said about the necessity of keeping the furnace working regularly. There was one point that had not been mentioned; with all the care that could be exercised at the blast furnace, he did think it was advisable to take the iron from one
1089 furnace, but they might get an average mixture by taking it from two. They found no difficulty in taking three tons from one furnace, stopping the furnace up again, and then going to another. He might state that he had timed their operations, and found that from the time of tapping the first blast furnace to the making of a finished rail (a rail between 60 and 70 feet long, and 80 lbs. to the yard), the whole operation—tapping the furnace, taking the iron to the converter, blowing, putting it on the bank, and finishing it—occupied one hour and nineteen minutes, and he thought that was about the quickest time in which it could be done.

The PRESIDENT: It would be rather interesting for us to know the time occupied in going from one furnace to another taking the iron from two furnaces, how long it requires from the moment you begin to tap the first furnace until you get it into the converter and what follows.

Mr. Snelus said it took six or seven minutes to tap the furnaces, four or five to weigh and convey to lift, and eight or ten to lift and pour into the converter.

The PRESIDENT: About 20 minutes, then?

Mr. SNELUS: Yes, about 20 minutes.

The PRESIDENT: That really is the point.

Mr. SNELUS: It took some time for the iron to run into the ladle. They could not send it in at a great speed, although their subway was close to the furnaces. He placed their subway for taking the

ladle as close to the furnaces as possible, as he thought that was an important point. At Barrow, the ladle subway was put at the foot of the pig bed, and the hot metal had a long way to run. He (Mr. Snelus) thought the closer they could put their ladle to the furnaces the better, because they certainly cooled the metal and made a good deal of runner scrap which had to be dealt with. He might also state in corroboration of what Mr Smith had said, that the quality of the steel made direct from the blast furnace was certainly better than where the iron was melted in the cupola. They had
1090 just recently been making some steel boiler plates of a very high quality, and in no case had they any difficulty in making those plates with the iron direct from the blast furnaces, while such excellent results had they obtained, that in one case he had had boiler plates stand 29 tons to the inch tensile strain, and stretch 35 per cent. before breaking, whereas they commonly stretched only about 20 per cent. The analyses also had been very carefully followed up, and corroborated these practical tests. The only point on which he was not quite satisfied was the yield. He thought the yield might be improved in the way he had pointed out. He did not consider that their saving of labor would amount to quite as much as they expected. He himself had put it at 1s. per ton. He did not think it would exceed that, but they would save the cost of coke in melting, which was a most important item.

The PRESIDENT: At what have you put, very roughly, the saving?

Mr. SNELUS: I do not think it will amount to more than 4s. or 5s. a ton at the outside.

The president said he saw his friend, Mr. Sharp, in the room. He had not had, and was not likely to have, any experience in the direct mode of making Bessemer steel, but no man had been more successful in making steel, so far as quality was concerned, and he would be very glad if Mr. Sharp would give them his opinions.

Mr. Sharp said that, not having had any experience on that subject, of course it had been quite a surprise to him to be called upon to make any remarks upon it. He had heard with very great interest what Mr. Snelus, Mr. Smith and Mr. Richards had said, and the results certainly appeared to be very successful. As a Bessemer steel-maker of some years' standing, that being the principal manufacture in which they were engaged at the works he managed, he must say they had always considered it was desirable to use more brands of iron than one—that by using, say, an average of about four brands of iron, they were much more successful in the
1091 results obtained than by using only one or two—they found that all the irons they bought varied very much in quality, and that, to his mind, had always been the great obstacle to running the metal direct from the blast furnace into the converter, particularly where they wished to have steel of a high and uniform quality; they had never yet met with one iron that they could — on working week by week, and month by month, without getting into trouble, and by using more brands than one they could of course get a much more uniform quality, and as one brand varied they

threw a little out and put a little of another in, and so on. He thought he was perfectly justified in stating that it was by having adopted that system and having given very careful attention to the quality of the materials they bought, that the steel manufactured at their works had acquired the reputation that it had done.

The president said he thought that Mr. Bessemer ought to say a word or two on that subject. It was a very old one with him.

Mr. Bessemer said he thought, after what had been said, there was scarcely room for observation. However, he might at least state that he was exceedingly gratified to have heard the account given by these gentlemen of the practical working of iron by his process direct from the blast furnace. The earliest idea he himself had ever entertained of the converting process was by the employment of molten metal direct from the blast furnace, and it was only because he had not access to a blast furnace in his first experiments that those experiments were made with remelted pig iron. No doubt it was of great advantage to him that he had only recourse to pig iron, because it afforded him the favorable opportunity which the last speaker had dwelt upon, and, like him, he was enabled to select his metal for many samples. In his earliest experiments, he happened by a great chance to buy some excellent Blænavon iron,
and obtained a result so satisfactory from the particular batch
1092 of iron which he had bought to experiment upon, that he was
led to the conclusion that every kind of iron throughout the kingdom would answer the purpose. The very next kind of iron he tried was that produced by their friends at Dowlais, and he need not tell them that they were at that time making a material that was not suited to his purpose. He could assure them that turning from one of those qualities of metal to the other gave him the greatest blow he ever received. His fine-spun theory, that all kinds of iron would answer the purpose, was knocked on the head in an instant, and he thought it took him something like two years to recover from that blow. He had tried almost every variety of English iron, and with almost every one he was successful. He then thought it necessary to try if he could obtain some comparatively pure pig iron, or such at least as was free from phosphorus and sulphur, and then, if his process succeeded with metal of that quality, there was some hope of his eventual success; but if he did not succeed with such iron, he must give the whole thing up as a failure. He then obtained some Swedish iron of an excellent brand, and the result was most satisfactory; it proved the fact, that if they had to deal with pig that contained only a minute quantity of sulphur and phosphorus, they could produce an excellent result. That gave him heart to proceed again. He then discovered, in looking at the various iron ores of England, of which he must say he was exceedingly ignorant at the time (not having turned his attention to that subject), he found that in the Whitehaven district an excellent ore existed which they all knew now as hematite. He purchased some hematite iron of the Workington Iron Company. His friend, Mr. Riley, and another chemist in London, made him several analyses of that iron, and he found to

his astonishment that it contained a large quantity of phosphorus, although the analyses of the ore showed that there was little or no phosphoric acid present. He went to the company and he said to them, "If you have any great secrets, pray do
1093 not convey them to me, but if you have none, will you kindly tell me all you do; let me see all you do in the production of this iron, for I have bought iron of you containing a very large percentage of phosphorus, and I find the ore from which you are making it contains scarcely a trace." They placed everything at his disposal, and he examined the whole of the works, and was unable to discover any cause which could account for the excess of phosphorus. In returning, after two hours' inspection of the works, he saw a large heap of material lying in one corner of the yard; he said, "What is that?" The reply was, "That is some flux which we use." He then said, "What is it?" and was told, "You know we sell a good deal deal of our fine hematite ore to the people of Staffordshire, and they fettle their puddling furnaces with it, and we buy it back again; it is an excellent flux for our iron." Thus he discovered that they sent their pure ore to Staffordshire, and there it picked up the phosphorus from the inferior metal of that district and brought it back again into the Workington iron. He (Mr. Bessemer) asked if they would make him 100 tons of iron from blast-furnace charges, which he would dictate, and to which they assented. He then had carefully analysed three samples of ores, of lime, and of coke, which were accessable in their district, the analyses pointing out the purest of those three materials, and he put in a certain quantity of clay or shale to make up for the absence of the slag from Staffordshire. They made him 100 tons of iron in this way, and they stamped it with a "B" to distinguish it from their ordinary metal, and this was the first Bessemer pig made expressly for the process, and it gave him so excellent a result that, from that period onwards, they progressed until they had arrived at the results of the present day. He must say (to return to the last subject that had been spoken to) that he was exceedingly gratified to see that it was quite practical to work iron successfully by his process direct from the blast furnace; he had, himself,
1094 proposed the tapping of three furnaces into one ladle or receiver; and when he advised some of his friends, in a company with which he was connected in the neighborhood of Barrow, to go into steel-making, they arranged their works some two years ago, so that the pig iron could be tapped into a ladle, or rather into a spherical vessel with an almost close top to it, that would hold 20 tons. It was proposed to make at least three 7-ton tappings into that vessel, and to move it on wheels into the converting house, using a pair of converting vessels, one after the other, until the four charges of five tons each were worked off; having a second ladle or vessel on its journey to supply, so as to keep on working continuously, and thus retain the heat, and form no scull at all in the ladle during transit, and, in fact, effect what had, by very similar means, been done by those gentlemen who had just spoken, and which they appeared most successfully to have accomplished. He must

in conclusion, congratulate them very much on their success, and say also how exceedingly gratified he was to find that his earliest ideas had thus been brought into successful operation.

Mr. Carbutt said he thought, in Mr. Bessemer's paper read before the British association, he claimed to deal with the iron direct from the blast furnace, because he (Mr. Carbutt) remembered at the time it made so great an impression that a good many of the blast-furnace proprietors determined to try it, and the manager of the Parkgate Iron Company then went into some experiments in order to make steel direct from the blast furnaces, which he attended, but, unfortunately, the thing was not successful; they had not blast enough, and the whole thing dropped through; but still it showed that Mr. Bessemer then claimed to work direct, and he wished to put this historical fact on record, for on examining the records of the British association no account was given of the paper, as
1095 doubtless many people considered Mr. Bessemer's theories, to say the least, visionary, and that might account for it not having been printed.

Mr. T. Whitwell said he would like to ask Mr. Smith if the furnaces at Barrow worked as regularly upon the close top as they did upon the open-top system of charging, as this was a subject intimately connected with economy in the direct process of Bessemer steel making. He imagined from the paper read last year by Mr. Deby, of Brussels, the excellent results spoken of at Seraing had to do with the regular working of the furnace, and he had written to Seraing a week before to ask how the furnace was working on the open-top system, and he read to the meeting an extract from the letter which he then received in reply, in which the open-top system of charging was spoken of in most favorable terms.

The president invited Mr. Bell to say a word or two on the subject.

Mr. I. Lowthian Bell, M. P., said he felt that some apology was needed from him in rising to offer any observations in connection with the subject under discussion. During the course of his experiments he had made one or two trials in reference to the effect of the cupola on melting iron, and he noticed that his friend, Mr. Richards—as well as Mr. Snelus, also, he thought—spoke of there being a considerable diminution of the silicon in iron by its passage through the cupola. Now, it was true that in melting iron, sometimes the silicon was notably diminished in the cupola, but occasionally there was little or no diminution whatever; but supposing that the change took place which those gentlemen alluded to viz., that they got rid of the silicon in the cupola—he would like to ask them how they expected to effect that separation of the silicon from the pig iron in the cupola without there being at least as great a waste there as there was from freeing the iron from its presence in the converter; he would, therefore, hope that the extra loss alluded to by Mr. Snelus was probably a matter which might be got
1096 over in time. The presence of silicon, of course, was an evil; that was to say, it was an evil so far as the unavoidable loss was connected with its presence in pig iron; but probably the pres-

ence of a certain proportion of silicon was useful in maintaining the bath of iron at that temperature, without which it would be impossible to produce steel without a great loss by burning iron. Naturally, any one who knew the great uncertainty connected with the manufacture of pig iron must necessarily be prepared to admit that there was considerable variety in the qualities of iron produced, and the plan adopted by Mr. Sharp was, of course, a reasonable one—seeking by mixture to remedy the defects proceeding from an excess of impurity in the iron by counteracting it by the absence, more or less, of those ingredients in other samples. He was always glad to listen to any discussion in which the great utility of the iron and steel institute was made apparent, and he quite well remembered the discussion which took place at Barrow, under the auspices of Mr. Smith, and at which he and Mr. Schneider were also present. He remembered the very expressions that fell from the lips of those gentlemen, when it was suggested that it was possible to make good steel by running the iron direct from the blast furnace.

Mr. Schneider said he would like to recall Mr. Bell's thoughts to one fact, viz., that in 1874 (the time to which he referred) steel rails were very much higher in price than they were now. The decrease in the price of iron and steel had sharpened the Barrow wits more than anything else.

The president said he thought they might consider that a very ample explanation.

1097 *Journal of the Iron and Steel Institute.*

London, 1876.

Pages 420–427.

THURSDAY, 21*st September*, 1876.

The president called upon Mr. Snelus to open the discussion on "The use of molten iron direct from the blast furnace."

Mr. Snelus said his present object was to describe the plans which he had adopted at the West Cumberland iron and steel works for conveying the molten pig iron from the blast furnace to the converters. In devising these plans he started with the conviction that it was desirable: 1st. To construct a ladle and carriage that could be moved about with safety and celerity without being of an undue weight; that the ladle should be placed in the most secure position upon its carriage: that it should be easily tipped for pouring out the metal; lifted out with facility when it required to be changed; and that the man in charge of the ladle should be in a good position for turning it over, so that he could not only see well what he was doing, but be out of danger from any splashes of metal. 2d. That all turn-tables and lifts should be avoided. 3d. That in order to produce the utmost economy the ladles should be brought as near as possible to the blast furnaces, so as not to cool the metal or have more scrap than necessary, and that the metal should be poured directly from the ladle into the converters, in order to avoid

the cost and waste of the runner-making. The diagrams would show how far these points had been met. Drawing No. 1 represented the ladle and its carriage in plan and elevation. There was nothing particular about the ladle, which was constructed to hold about eight tons, and of such a shape that its contents could be poured out over a lip on either side. It was supported in
1098 the center of the carriage, whereby the greatest stability was obtained without the need of any balance weight, and its center of gravity was conveniently low. It was turned over by a simple cast-steel worm and wheel. The carriage was built of strong wrought-iron frame plates, somewhat after the construction of a locomotive frame, and was provided with steel axles and tuyeres and supported by strong carriage springs so as to run perfectly steady. The details of the construction could be seen from the drawings. The carriage and ladle lined up ready for use weighed under 10 tons. Drawing No. 2 showed the position assumed by the ladle when its contents were being poured into the converter. Drawing No. 3 showed the arrangement adopted to enable the ladle to be brought up to either converter. The converters were arranged according to the usual English plan facing each other, and a staging had been thrown over the pit between the two converters. This was supported by the back wall of the building, and by a strong steel girder over the pit stretching between the supports of the two converters.

This was at a sufficient height to leave plenty of head-room for the platform center crane, and at the right level for the ladle to pour clean into the vessel. There was a separate pair of rails for each converter. Drawing No. 4 showed the relative positions of the blast furnaces and converting sheds. The distance between the two points was about 350 yards, and, as would be seen, they had contrived to get a comparatively direct line from one point to the other. In order to bring the ladle as close as possible to the furnaces, a cutting had been made through the pig beds in front of the tap-holes, and in order that the pig beds might not be curtailed, the cutting was made sufficiently deep to be covered over for casting purposes. Drawing No. 5 showed a vertical section of the cutting. There was sufficient head-room for a locomotive to work the traffic entirely. In practice they always tapped the iron from the furnaces into the ladle, about 3 tons 10 cwts. from each furnace. This was done to ensure, as far as possible, a uni-
1099 form charge, and there was very little difficulty in doing it.

Five minutes often sufficed to tap both furnaces and to get the charge of metal, and in less than five minutes it could be weighed, taken to the converters, and poured into the vessel. It was evident that the arrangements were such as would produce the minimum amount of scrap and skull, and they consequently found considerable benefit from the increased yield. One ladle would last from twenty to thirty casts before the skull needed to be taken out, and even then it was only the loam coating and not the brick lining of the ladle that wanted renewing. The practical results obtained for the previous fortnight had been: Total metal used,

1,033 tons; ingots made, 887 tons; ladle skull iron, 14 tons, 12 cwts.; iron scrap cleanings of ladle, 1 ton, 3 cwts.; steel scrap of all kinds, 14 tons, 7 cwts.; yield of ingots, 85.8 per cent. on 14.2 waste; iron skull and scrap, say, 1.5 per cent.; steel scrap of all kinds, 1.5 per cent., leaving absolute waste about 11 per cent. Comparing this with the results he had given at the last meeting when they were pouring the metal from the ladle down a long runner to the vessel, all the cost of making the runners and also of 2 per cent. of iron was saved by pouring the iron direct into the vessels. Although there was not much novelty in the arrangements described, they had required to be carefully and cautiously worked out, and he desired to acknowledge the hearty co-operation he had received from the engineer to the works, Mr. Thomas Wood, and his assistant, Mr. Croasdel, and from the blast-furnace and Bessemer managers, Mr. Harrison and Mr. Salter, who had spared no pains to make the plans successful.

Mr. J. T. Smith said that when he had the opportunity of bringing that subject forward at their last meeting, he had not then had a sufficient amount of experience to enable him to treat very definitely upon the results of that plan of making Bessemer steel, and therefore he spoke in such terms—at least he intended to
1100 speak in such terms—that if he found it necessary to modify his opinions when he had to come before them again, he could do it with some amount of grace. Since that time they had taken across from the blast furnace to the converters every week from 1,500 to 2,000 tons. Their arrangements had not been materially modified during the time, and they were working upon the same principle that he explained to them at their London meeting. Their arrangements, in some respects, he considered inferior to those designed by Mr. Snelus, partly in consequence of their works not having originally been laid out for that process, and partly because there was a peculiarity about their iron which did not pertain to the Workington iron, he believed. They need not be in the same hurry to influence the Bessemer operation, as was necessary with the iron made from West Cumberland ores, and therefore the railroad they had for their ladle at the pig bed was at the opposite end to that arranged by Mr. Snelus. He (Mr. Smith) was perfectly satisfied that Mr. Snelus's arrangement was, as a rule, superior to theirs; but seeing that they had 14 furnaces in a row, and that that row was of considerable length, also that they wanted to take iron from various furnaces, he considered that the inconvenience which would arise from carrying on their iron business by bringing the railroad so near to the furnace, seeing that it was practically impossible to sink their road so completely as Mr. Snelus had done, necessitated their being at the other end of the pig bed. So far as Mr. Snelus had detailed the results as to the scrap that was made in the iron ladle, they seemed very much to accord with their experience. During the six months that had elapsed since he had spoken upon the subject before, they found their scrap in the ladle was about 1¼ per cent., and the results of their working during that time were identical, so far as the quantity of

steel that had been produced from a ton of molten iron was concerned. He (Mr. Smith) maintained still what he stated on the previous occasion with regard to steel works arranged with blast
1101 furnaces, that one of the great advantages of that process was the regularity they were obliged to have with respect to the blast-furnace operations, because so sensitive was the Bessemer converter—at any rate in the case of the iron they made—that with a very small alteration in the proportions of the various classes of hematite ore used by them, the difference in the steel produced from the converter, instead of being about 14 per cent., was found running up occasionally to even 30 per cent., so that the moment such a result occurred they went to the blast-furnace management for an explanation of the waste, and he was bound to reiterate that he considered the main saving they had in conducting their operations in Bessemer steel making really was because they were managing their blast furnaces better than they had been before. He had also the satisfaction of stating a fact which he knew would be confirmed by Mr. Snelus and any other gentleman who was adopting the same process, namely, that so far as the quality of steel was concerned, their experience showed that they really obtained, upon the whole, a better class than they formerly had when they melted their pigs in the cupola, and the entire operation was so far commercially successful. If at any future time some other members of the trade found that they could deal with iron in a better way than from the blast furnace, he trusted that they would not be slow in following those persons in their whole practice.

The president said that when last that subject was before the institute they were making preparations at Dowlais for bringing the metal hot from the furnaces. Since that time they had carried out the plan, and were working, as he thought, very successfully. Like Mr. Smith, owing to the position of their works, and their not having been designed for working in that way, they had had several difficulties with which to contend, and he was afraid it would be impossible to introduce the direct pouring of the metal into the converters as Mr. Snelus had done at West Cumberland,
1102 which must, of course, be an advantage; so far, they were using runners. The only difference between their mode of dealing with the iron, and that which Mr. Smith had introduced was that they went in for tapping the ladle instead of tipping it. This enabled them to use a very simple carriage and that he thought was an object. They had used the tapping ladle from the beginning, and he saw no reason to alter his opinion as to the merits of the plan, taking into consideration the circumstances under which they were working at Dowlais. They had gone very carefully into the question of the amount of ladle scull made; the loss was as near as possible that stated by Mr. Snelus. He (the president) was very far from saying that tapping the ladle was better than Mr. Snelus' or Mr. Smith's plan of tipping, but it would be of some interest to them to know that it did answer the purpose well, and that it enabled them to make a carriage that was very compact and simple. He did not know that he had anything further to say than that Mr.

Snelus, with his usual ingenuity, had devised a very neat mode of getting the iron into the converter, but whether it could be introduced at old works was a question. Mr. Richards had taken up the same idea, and worked it out with his usual skill. As far as his experience went, the plan of taking the iron direct from the blast furnace was working admirably. A considerable saving was effected; he might also say that it did not interfere in any way with the quality of the steel. He did not assert that the steel was better, but certainly it was no worse, and, upon the whole, the plan at Dowlais was working very satisfactorily indeed. They had taken about 900 tons in the last week, and he expected that by and by they would take a great deal more from the furnaces. Their furnaces were not conveniently situated. They ran the molten iron down an incline of about 1 in 55 over a rather complicated road, and instead of taking the iron as Mr. Smith did (and properly so in his case) from the end of the pig bed, they ran the ladle up into the cinder fall.
1103 There had been no alteration in the furnace. They had height enough for their ladle. It was simply run up and filled as near the tapping hole as possible, not so near as by Mr. Snelus' plan, but practically so; thus that part of the business was satisfactory. As to dealing with the Sunday iron, a subject to which Mr. Williams had very properly alluded at this and previous meetings, it was a difficulty, and he was afraid it could only be met by working all round the week as they did in the blast furnaces, or, at all events, to something near it. It would be a great economy, and he confessed he was afraid that even home and foreign competition would drive them to it. Mr. Snelus seemed to have gone a step in the direction indicated. At Dowlais they began practically at 12 o'clock on Sunday night; at present they finished on Saturday evening.

1104 *Journal of the Iron & Steel Institute.*

London, 1878.

Extract, page 104.

The manufacture of Bessemer steel and steel rails at the works of Messrs. Brown, Bayley & Dixon (Limited), Sheffield.

By Mr. C. B. Holland.

The president said the meeting would now proceed with the discussion on Mr. Holland's paper on the manufacture of Bessemer steel and steel rails; and he invited Mr. Maynard to give some information with regard to melting.

Mr. Maynard referred to the article which had appeared in the previous week's Engineering (March 22) with regard to the output of Bessemer steel at the Chicago works for the month ending the 1st of February last, from which it appeared that the output from a pair of 5-ton vessels averaged 3,100 tons of 2,240 lbs. each. As an American, he had great satisfaction in calling attention to such a

large output. A very important feature in the improvements which Mr. Holley and his very able assistant, Mr. Cooper, had introduced, was their very excellent cupola practice. When they got down to 1¼ cwt. of coke in the melting of pig iron, it became a question whether the tapping of the metal direct from the blast furnace was any longer necessary or advantageous. Mr. Holley had of late taken very decided views on that subject, and had quite come to the conclusion that the hoped-for advantages had not resulted altogether, because you had not absolutely in your control to get a uniform metal from the blast furnace. If you could work out your various brands of iron as those steel works that had to buy pig iron were under the necessity of doing, then of course it would be much more under control. The objection which had been raised up to this time was the cost of remelting; but the hot-blast cupola seemed to overcome all the difficulty.

1105 Mr. Snelus, in offering a few remarks on Mr. Holland's paper, desired to acknowledge the extreme courtesy with which that gentleman and his officials always received those of the trade who went to see the excellent work he was doing. He had himself had the pleasure of seeing the works several times, and they had always been shown in the most open manner. He could not help bearing testimony to the very excellent work that was done there, and there was only one respect in which he thought Mr. Holland fell short. Instead of using 1¼ cwt. of coke to melt his ton of pig, it would be better if he did not use any. It might be that they were unfortunate in Sheffield in not having their blast furnaces sufficiently close to their works to enable them to take the iron direct. That, of course, they were very sorry for. There were, no doubt, difficulties in the way of working iron direct from the blast furnace, and he was rather surprised at the statement Mr. Maynard had made as coming from Mr. Holley, because he had himself been in correspondence with Mr. Holley, who had informed him that at Bethlehem works Mr. Frith was doing half their work direct from the blast furnace, and had for some time had under consideration the idea of a receiving ladle, so as to receive the metal from the blast furnace, and hold it in readiness there for the converters. One great drawback to the direct-casting process was, that you could not always get your metal at the exact time you wanted it. He believed it would be found that the great advantage the Bessemer works in America had was the intermediate receiving ladle, which was designed by Mr. Holley, and which was universally used there, although it was never used in England. The Moss Bay Company attempted to modify the thing some time ago, and put up a heating furnace, but that, to his mind, was a step in the wrong direction. Anyhow, the thing had failed, and no one in England, as far as he knew, was using any intermediate receiver between the blast furnace and the converters. He thought himself that the

1106 receiver was of considerable importance, both for saving time and for facilitating the admixture of iron, and he was confirmed in that view by the idea of Mr. Frith, of Bethlehem, who was about putting up a 30-ton ladle, according to Mr. Holley, to receive

the metal from the blast furnace and hold it in readiness so that at a moment's notice you could take your iron into the converter and also obtain a better mixture. With himself (Mr. Snelus) it was a question of expense, and he was sorry he had not been able to apply it on that account. Having had experience of and witnessed the work done at Messrs. Brown, Bayley & Dixon's works he was struck with the cupolas and having examined carefully the working of the hot blast as derived from the waste products of combustion from the converter, he must say it had gratified him very much to see that the waste heat from the converter had been utilized. It might be remembered that he had suggested the desirability and possibility of using it on the occasion of the Merthyr meeting, when he calculated the quantity of heat that was going to waste. But, of course, there were difficulties in carrying out even a suggestion, and it did not fall to the good lot of everybody to be able to carry out that which they might see was in itself quite right. He was very glad, however, to see that Mr. Holland had been able to do it and had succeeded so well. When he visited these works he found that the temperature of the blast going into the cupolas was about 400°, and it seemed to be very constant, and no doubt that was a great element in the saving of the coke. It enabled the cupola to work more quickly and freely, and it also saved coke in consequence of the extra heat that was carried into the furnace by the blast. There was another point of importance which might, perhaps, escape the notice of those who had not been to the works, and that was in the cupola practice. For blowing Mr. Holland used a large blowing engine, and not the apparatus used in most steel works, a blower. He got a pressure of about 1 lb. to the inch for his cupolas, and that, no doubt, had a great deal to do with
1107 the regularity and rapidity of the working. With respect to the ascentional casting of the ingots, he must say that, like everything else there, it was done remarkably well. Perhaps he (Mr. Snelus) was not one of the first, but he did make attempts to use a similar casting several years ago at his works, and he was sorry to say he failed, not because there was more difficulty about ascentional casting than any other but because it so happened that his pits were 9 feet deep and only 11 feet in radius and there was not room to place two sets of moulds in the pit at one time. Therefore, it was on that ground that he had very reluctantly had to give up the ascentional casting in his own place. But he was convinced that there was a great saving to be made by that method of casting. He did not think Mr. Holland could so successfully carry out his single heating of ingots if it were not combined with the ascentional casting. He had himself attempted on many occasions to roll ingots off at a single heat, and he had succeeded in rolling two or three-length rails. He would like to ask Mr. Holland one or two questions that might be interesting. One was as to the absolute waste he found in single heating of his 11-inch ingots, and the other was as to the average amount of crop ends over a period of three months, which he found he got by ascentional casting. Those

figures were not included in the paper, and if Mr. Holland would kindly give them they would be of service to all concerned.

(Endorsed:) U. S. Patent Office. Copy made April 7, 1896.

1108 *Engineering.*

Colburn.

London, 1874. Vol. XVIII, page 310.

The Bessemer Process.

To the editor of Engineering.

SIR: Having just read your report of the discussion at the late meeting of the Iron and Steel Institute of the desirableness of converting by the Bessemer process crude iron immediately it is tapped out of the blast furnace, I am moved to write you about a plan developed by me some three years ago for overcoming some of the few principal difficulties which have been met in such practice.

Görausson, of Sweden, made the first successful conversion of metal taken from a blast furnace, in 1858 I think, and this mode of conducting the Bessemer process is still practiced on a large scale in Sweden, and in Germany and Austria, when the iron is taken from small furnaces using pure and more or less manganese ores.

In the later attempts to carry on direct conversion of metal made in large furnaces with coke, and from the hematite and magnetic ores now so generally used, it was found that the varying character of the metal so produced made it difficult, if not generally impracticable, to make uniformly good steel; and further, it was impossible to arrange the tapping of the blast furnaces to coincide with the needs of the converters.

Hence steel-makers have generally preferred to incur the costs of running the crude metal into pigs, of handling and remelting it, with the consequent loss and waste, in order to have the opportunity of carefully selecting and mixing the pig irons for each charge to be converted.

To gain the greater part of the saving arising from converting the iron directly it is tapped from the blast furnace, and to
1109 obviate the troubles arising from the variations in character of the product of the average of blast furnaces, and also to be able to mix irons to any reasonable extent, I devised the following, as it seems to me, simple and practical plan:

I proposed to erect at some convenient place as near as possible to the converters, one or more gas reverberatory furnaces of sufficient size to hold the average tap of the blast furnaces supplying the metal for conversions, and then run or pour the crude metal from the blast furnaces into these gas furnaces, where it could be alloyed or treated as desired, and thence be tapped out from time to time as required by the converting operations.

It is well known that gas furnaces can hold molten iron in a fluid state for a considerable time with but little variation in its character,

and very small cost for fuel to maintain its heat, and it is manifest that while the metal is thus kept it can be easily alloyed and mixed at will.

If the iron is not gray or carburized enough, or not silicious enough, grey or silicious pig can be melted down with it to produce the desired standard; and, as with gas furnaces, any required heat may be given to metal under treatment therein at a very small cost, it will be possible when metals are to be used, which do not contain sufficient carbon or silicium, to permit their being converted and cast into ingots if put into the converters at the heat of ordinary charges to heat these metals so highly as to overcome all the difficulties usually met with irons which "work cold."

Indeed, all conversant with the Bessemer process and with the mixing and melting of pig irons will, I think, see that with a reasonable supply of suitable irons for mixtures, and with the facilities for treatment arising out of the manageableness of gas furnaces, a continuously good average standard of iron for conversions can be maintained on my plan from one year's end to another.

1110 I do not propose in this letter to dwell on the various advantages derivable from my plan, but I will illustrate more fully one of its possibilities already alluded to.

In the more common practice under the Bessemer process it is usual to have the charge of iron contain from 1½ per cent. to 3 per cent. of silicon, besides as large as possible a content of carbon, the percentage of the silicon being made to increase or decrease in an inverse ratio with the amount of carbon contained at the same time. The object is to provide such an amount of fuel in the metal that the air forced into it will develop so high a temperature that the metal will not only be kept in a proper state during its conversion, but also be hot and fluid enough when poured into the casting ladle to enable it to be tapped out without leaving any scull or waste.

Of course this fuel, which is burned out of the pig iron in the converting process, costs just what the iron itself does, say, at present prices, 100s. to 105s. per ton.

Now fuel suitable for a gas furnace will at most iron and steel works cost but little if any more than 8s. per ton, and it will not take more than one-quarter of a ton of this fuel to raise each ton of iron to be converted from the molten condition in which it comes from the blast furnace to about the heat and fluidity needed in successful operations in conversion, and if my theory is right, the high-cost fuel usually combined in the iron converted can be replaced to a considerable extent by common coal slack, and a more absolute control over the converting process be secured.

There should be no difficulty in adapting my plan even to existing works, as will be seen from the following facts.

The quantity of iron now converted at once in Bessemer works is so large, that even after it has been tapped out into a ladle or run into the converter it may be retained in a sufficiently hot

1111 and fluid state for the converting process for a long time, and I have known it to be so kept for several hours.

At least the metal can be so held as to permit it to be carried on a tramway as far as convenience would ever require, and thus the gas furnaces be located very much at will.

I am convinced that it would be an improvement on most plants working the Bessemer process to have the furnaces for melting the iron further away from the converters, as such an arrangement would leave much more clear space about the converters, and make it easier for the men to work around them. In most American works the pig iron is hoisted to cupolas built up high enough to permit the iron melted in them to be tapped into a ladle and then be poured into the converters.

This plan necessitates the hoisting of the fuel also, and the cupolas make a constant mess near the converters.

Ordinarily it takes half a dozen hoistings of metal and coal to provide one charge of molten metal for the converters, while if the iron should be melted away from the converting works, it could be brought to them easily on a tramway and handled at one operation. And even if the metal should then be melted in cupolas, the cupolas could be set more conveniently and with considerably less expense than in our practice, and owing to the freer access around them a saving of labor would result.

I have never been able to comprehend why the change from ordinary reverberatory furnaces used formerly in melting iron for the Bessemer process to cupolas should have been made in England where the value of gas furnaces is, or should be, so well understood.

Whatever saving was made in fuel by changing from the old reverberatories to cupolas would have been nearly or quite equalled by using gas furnaces, while the diminished waste of iron in
1112 its remelting in the gas furnace instead of in cupolas would have been a source of great economy.

I have understood that the Siemens gas furnace was used at the Mersey works for melting Bessemer pig and abandoned; and as Mr. Siemens admits that a moderate decarburization and desilication will take place if metal is merely held molten in his furnace for a considerable time, I can suppose that if the furnaces at the Mersey were used only to melt the iron that the less carburized and silicious irons so melted might have worked cold in the converters.

This difficulty should have been obviated by running up the temperature of the iron before putting it into the converter, and it would be a great satisfaction to know if this was ever tried, and if so what were the real grounds for the abandonment of the gas furnace.

Experience in this country, as stated by Mr. Holley in his paper at the last meeting of the institute, demonstrates a saving of 5 per cent. by the Siemens gas furnace in heating iron, as compared with the results of ordinary heating furnaces doing the same work; and if the same proportionate saving would take place in melting iron as in heating it, the gas furnace should melt with little or no waste or decarburization.

I have been told by one of the leading iron founders of Pittsburg that his average waste of iron in a year's work in melting iron for

rolls in ordinary reverberatory furnaces is only 3½ per cent.; and with an approximation only to the economy reached in heating, a gas furnace should bring the waste of melting iron down to 2 per cent., which is only about half the waste in average cupola practice.

If, then, large gas furnaces capable of melting, say, 10 tons per hour should be located sufficiently near converters, it will be seen that a vast deal of handling of metal and fuel could be saved, as all the operations could be carried on on the ground, and then a lift conveniently located at the converters would at one operation handle a charge brought to it, and pleasanter and more convenient working would be insured.

1113

With regard to the necessary proximity of the blast furnaces, gas furnaces, and converting works on my plan, I will say that as crude iron can be held safely in a molten condition longer than it can be after it is prepared for the converters, such iron can be taken to the gas furnaces from the blast furnaces over distances of a mile or two even, if proper preparations are made, and there are no public reasons for preventing it.

The arrangement for tapping the blast furnaces can be made so as to permit the molten iron to be run into ladles to be taken to the gas furnaces or into a pig bed as usual, so that if a furnace chances for the time being to be making greyer or more silicious iron than is needed for immediate use, such iron can be cast into pigs and be saved for mixing with other irons when mixtures are needed at the gas furnaces.

In discussing the practicability of working the Bessemer process with irons drawn more or less directly from the blast furnace, it must be understood that the ores used in the blast furnaces shall be naturally adapted to making suitable iron. There may be no insurmountable difficulty in so managing the charges and the working of furnaces, as that with good ores a product of iron for the Bessemer process, meeting all its necessities can be made regularly and continuously, but I see no way in which the metal can be satisfactorily taken from large blast furnaces just when it may be wanted for conversions, and the use of a gas furnace intermediate between the blast furnace and converters will afford a better chance of correcting the injurious influence of phosphorus, sulphur and other impurities in irons than we are likely to get otherwise.

I am, sir, yours truly,

Z. S. DURFEE,
56 *Broadway.*

New York, September 23, 1874.

1111 *Engineering.*

Colburn. Vol. XXIII. 1877. London.

American iron and steel works.

No. 1.

By A. L. Holley and Lennox Smith.

An Analysis of the American Bessemer Plant. Illustrated in the Vulcan Works.

Page 183.

The Bessemer steel works of the Vulcan Iron Company, at Carondelet, a suburb of St. Louis, on the Mississippi river, are partly illustrated by the two-page engraving which we this week publish, as well as by the view on the present page.* As this is the latest American Bessemer plant (having been started in July last,) and is, therefore, supposed to embody the various improvements which have been developed or suggested by the somewhat remarkable practice in that country, it will be made, in this the first article of the present series, the illustration of a very brief treatise on the general character and peculiarities of the American Bessemer plant.

That these peculiarities deserve analysis and consideration will appear from the fact which has often been referred to in the columns of Engineering, that the average production of two 5½-ton or 6-ton vessels in one pit, is, in round numbers, 40 heats, or 225 to 250 tons of ingots per twenty-four hours, while no less than 64 heats have been made, and above 350 tons of ingots have been produced in that time. It would be evident, even if it had not been abundantly proved by comparative yearly returns, that this celerity of operation is highly economical of labor, of fuel, and of general expenses. It should also appear that it is economical in respect of maintenance,

for the plant, as well as the men, must be kept in the highest
1115 state of efficiency to accomplish so great a result day after day. It is hardly necessary to suggest to the expert that machinery in thorough repair is subject to the minimum of wear, of delay and of attendance.

The objection sometimes made to a large output, that the quality of product may in consequence deteriorate, is not well founded. Waiting two hours between heats to set a vessel bottom that ought to be set in thirty minutes, will hardly affect the quality of the steel. And it is also true that an improvement in the quality of American steel has steadily kept pace with, although it has not exclusively resulted from, this enlarged production.

The history of the Bessemer plant and manufacture in America has been detailed in an able and interesting paper before the American Institute of Mining Engineers, (published in Engineering, vol.

* Further views, Figs. 4 and 5, will appear in our next number.

XXII, pages 509 and 532,) by Mr. Robert W. Hunt, general superintendent of the works at Troy. It is proposed in the present paper to treat the subject analytically rather than historically. The distinctive features upon which the manufacture depends for this very large and regular output are the following:

1. Facilities for handling material and product, and for repairs.

1. In the melting department,—no American works is as yet using fluid iron direct from the blast furnace, although the Vulcan plant is arranged, and the others may readily be modified to do so. The results of the arrangement of this department are to gather materials from the largest yard space; to place them where they are required, with the least interference and with little labor; to concentrate their products in the converting department by short and easy transportation; to conduct the debris into the yard without labor; to provide protection of men and apparatus against cold weather and more especially to mitigate the severity of the working heats in warm weather; and, what has an importance equal to any of these things, to provide the most ample room and convenience for repairs.

1116 By referring to the engravings of ground plan, Fig. 2, and cross-sections, Figs. 1 and 3, of the Vulcan plant, these features may be observed. The hydraulic lifts a a', Fig. 2, are situated at the corners of the building, in order to command the yard on three sides of it; iron, coke, and refractory materials may thus be stored over a considerable area, and yet be near their respective lifts. Hand wagons holding about a ton each are in every way more convenient than large railway tracks, chiefly because one man can manœuvre them, and they may be unloaded directly (thus avoiding some rehandling of material) into the large cupolas b, b, b, and into the spiegel cupolas c c and c' c', which are all charged from the same roomy floor. Refractory materials for use on the 28-ft. floor upon which the cupolas stand (see Fig. 1) are brought up by either lift, and those for use on the 11½-ft. floor behind the vessels, are raised by lift a 1 to that floor, which here extends the whole width of the building (see Fig. 3). The hinged bottoms of the large cupolas are dropped after the furnaces have run as long as they should run, and the considerable volume of remaining slag is thus cleanly discharged while it is hot and fluid, and it is discharged into the yard by means of the incline b, Fig. 3. Slag is constantly run from the cupolas as in blast-furnace practice, and this slag falls down the same incline, along with a stream of water which disintegrates it so that it is easily handled. All the slag might slide into dump wagons, and be at once removed at the least cost, but that from the hearth, when the bottom is dropped, is rich enough in iron globules to warrant its treatment in a "tumbling barrel." The comparatively small amount of spiegel-cupola debris is withdrawn from the breast as in the English practice, and is, together with all other cupola-house debris, thrown down the incline, beneath which an ample space commanded by a narrow-gauge railway is provided for its assortment and loading. But in case the metal for conversion comes directly from blast furnaces, the conveniences thus provided

for the spiegel furnaces and for the vessels do not in the
1117 least interfere with the convenient handling of the blast-furnace metal; on the contrary, this arrangement enables the convenient use of this metal in part and of cupola metal in part, as may be made necessary by the insufficiency of smelting plant or by the irregularity of blast-furnace iron. If the intention is to use chiefly blast-furnace iron direct, the judicious use of a cupola (lined to a less diameter so as to run economically on a small product) enables the manager to mix and temper his irons, much sooner than he could do so by the blast furnace alone, and so to get a uniform steel. There are two cupola ladles *f f*, Fig. 2, which are mounted on trunnions and provided with tipping gear; between these ladles there is the similar blast-furnace ladle *e'* on a car which enters the building through the gangway *i*, Fig. 5. Fig. 1 shows the side of this ladle and its car, and of the lift which raises it from the railway which leads to the blast furnaces. The metal from the ladles is poured into the vessels by means of spouts *n*, *n*, *n*, attached to the ladles, and leading to the common runner *g*, and thence to the swinging runner *h*, which conducts it to either vessel. It will be observed that this blast-furnace metal ladle, with its railway on the general level, its hydraulic lift, and its spout, is perhaps as convenient as it could be, were there no cupolas, while the cupolas are perhaps as convenient as they could be were there no blast-furnace ladle. The two systems are not in interference; on the contrary, they are auxiliary one to the other. An incidental value of the blast-furnace lift is to remove and take down to the yard quickly, by means of the traveller (see Figs. 1 and 4), a ladle scull, or either of the ladles *f f* which may need relining, and to bring up a spare ladle. The convenience of a very roomy tapping floor, all on one level for both the main and the spiegel cupolas, from which all the tuyeres may be inspected and cleaned, will be appreciated by experts. It will also be observed that all the operations going on in the cupola-
house may be observed from the converting-house, through
1118 large openings in the dividing wall; half the center opening and also the right-hand one are shown by Fig. 4. The concentration of the metal in the converting department, by means of various radial spouts *n n*, and those running to the spiegel cupolas, and of the swinging spout *h* which serves both vessels, is facilitated by making the inclination of these spouts very steep, so that the metal will run out rapidly and clean. For this purpose the various levels have been raised in successive works, until the cupola-charging floor is here 40 ft. from the ground. Hoisting the charges a few feet further, when they are once on a lift, costs an inappreciable amount, but the sluggish running of metal to the vessels is a source of delay and expense. The spouts and runners, except where a stream of metal falls directly upon them, are made of cast iron 2½ in. thick, and are properly washed and warmed before use which farther facilitates the clean running of the iron. Attaching the ladle spout to the ladle (by means of an easily detachable apparatus) prevents slopping and scrap. The cupola ladles *f f* facilitate the distribution of metal to the vessels. They form reservoirs which make the melt-

ing department and the converting department independent of each other, within limits. This advantage was not fully appreciated until the large productions of the last few years were attempted. Should any delay occur in casting, in preparing a vessel, or from any cause, the melting department keeps right on, for these three ladles will hold six vessel charges, which may be stored and converted when the converting department is ready for them. Cast iron will "live" in these thickly lined ladles, when covered with charcoal, for several hours. But it is necessary to put these ladles upon weighing machines, so that either uniform vessel charges may be run out, or so that the spiegeleisen may be proportioned to such charges as are run out. The ladles and their weighing machines stand on a small floor 20 ft. above the general level, partially under the 28 ft. or cupola floor. A front view of this 20-ft. floor is given in Fig. 4 and a section in Fig. 1.

1119 The protection of men against extremes of heat and cold is an important matter in America, and may well be considered in any country. Excepting the removal of ingots from the pit, charging the cupolas is the most hot and severe work of the men. It will be observed from Fig. 2, that the 40-ft. cupola-charging floor is very large, that there are a high roof and ample ventilators above it, and that it is surrounded on all four sides by windows. The elevation of this floor to get a rapid fall of the metal, at the same time raises it above the adjacent converting-house, so that any air that may be stirring makes a through draft. Winter protection requires merely the closing of the windward openings. In other American works the cupola-charging floor is placed over the cupola ladles. The advantage of placing it otherwise, as here shown, is, first, that it is nearer the greatest window area; second, that it is not heated by radiation and hot air from the ladles and from the molten metal, and third, that it does not interrupt the upward current of hot air from the ladles and vessels. The arrangement shown leaves a ventilating shaft from top to bottom of the hottest part of the building. The 28-ft. cupola-tapping floor is open on three sides to the outer air, and the wide 11-ft. floor behind the vessels runs from end to end of the cupola-house, and is ventilated by the shaft above referred to.

With regard to convenience and celerity of current repairs—a most important consideration—it will be observed, first, that while either cupola is stopped for repairs, the others may discharge into either ladle; second, that all three ladles may, by means of the ladle lift and traveller, be replaced or interchanged; third, that abundant room and ample platforms and stairways are provided for the dressing of the runners from the ladles and spiegel cupolas to the vessels; fourth, that because the cupola department is divided into several stories, ample room is provided in each of these stories for the refractory materials used in them; fifth, that for the

1120 same reason there is a large space at one end of the cupola building, which is not otherwise required, and which is thus available for the preparation of refractory materials by means of crushing and grinding mills and their driving engine; these are

not shown in the engravings. The cupola lift and the successive stories thus afford, with very little extra expense, the most convenient facilities for the preparation by successive stages—falling out of one machine into another—and the ready distribution of refractory materials.

Engineering.

Colburn. Vol. XXIII. 1877. London.

Page 357.

The Pennsylvania railroad.

No. XIX.—The Altoona shops (continued).

5. The wheel foundry.—This is a new and very important addition to the Altoona works. It forms a wing of the same building, as will be seen by reference to the plan, and is a brick structure with roof trusses of wrought iron; the roof covering is of slate. The main portion of the foundry, which is 138 ft. 6 in. long by 71 ft. 6 in. and 35 ft. high, contains the moulding floor. It is lighted by eleven windows each 21 ft. high and 8 ft. wide, as well as by a raised skylight containing sixty sashes. Ventilation is obtained by louvres in the raised sides of the skylight. On one side of this moulding floor are placed the cupola chamber 29 ft. by 40 ft., the engine-house, 30 ft. by 30 ft., the boiler-house, 30 ft. by 15 ft., a core-room and ovens of the same dimensions. The operations of annealing and finishing the wheels are prepared in a wing of the foundry, 94 ft. long and 56 ft. wide. The general arrangement is shown in the plan, and Figs. 11 to 18 show details of construction.

We have previously, in noticing the main foundry referred
1121 to the blowing engines, the hydraulic machinery, the vertical engines for drawing the machinery in the pattern shop, and the boilers, and we need not, therefore, again describe them. The wheel foundry is furnished with thirteen hydraulic cranes arranged as shown in the plan of the shop. The ordinary working pressure for these cranes is 450 lbs. per square inch. Each crane is free to swing entirely round, and controls a circle 13 ft. in diameter. As will be seen by the details, they are unsupported at the top but are well secured by masonry foundations. The jib does not rise and fall, but carries at the end a sheave over which a wire rope passes and is brought back to the centre of the crane, where it is attached to the piston of the hydraulic cylinder, the travel of which raises or lowers the weights to be moved. This portion of the plant was supplied by Messrs. W. Sellers and Co., of Philadelphia. The circle of 13 ft. diameter which forms the sweep of the crane, is sufficiently large to give space for fifteen moulding flasks for wheels 33 in. in diameter, which is the largest size used by the Pennsylvania Railroad Company. The exact position of each mould around the circle is marked by an iron ring that forms a level seat for the flask, so that little time is lost in arranging the flasks in their places and in the proper position for pouring.

We may here mention that the foundry floor is laid with cast-iron plates, provided with narrow-gauge tram grooves in which two-wheeled trucks are run, transporting the flasks to their respective places.

In the foundry and immediately beneath the cupolas A, Figs. 11, 13, is placed a large ladle B, holding about 20,000 lbs., and mounted on trunnions. This ladle is controlled by hydraulic power, and is completely under the control of the workman. Troughs C C from the tapping holes of the cupolas conduct the melted metal into it. It was found advisable to employ a
1122 ladle of so large a capacity, because by doing so a more completed mixture of the different irons is effected, than would be the case if a smaller vessel were employed.

There are two Mackenzie cupolas A A belonging to this department. They are rectangular in section, measuring 7 ft. 6 in. by 3 ft. 6 in. at the boshes, and 8 ft. 6 in. by 4 ft. 6 in. at the largest part; the distance from the tuyeres to the charging level is 9 ft. 6 in. These tuyeres form a continuous opening 1½ in. wide, and extend round the cupola, at a height of 8 in. above the floor, when the latter is ready for charging. No flux is employed in melting the charges, and no provision is made for tapping the slag. The average quantity of metal that can be run from each of these cupolas, before the tuyeres become so clogged as to impair the working, is 65,000 lbs. It is true that a larger quantity than this can be run off in a single heat, but it is found that so large a charge does not produce metal of a quality sufficiently good to fulfill the requirements for cast wheels.

1123 *Engineering.*

London, 1878. Vol. XXV, page 295.

American Iron and Steel Works.

By A. L. Holley and Lenox Smith.

No. XXI. The works of the Edgar Thomson Steel Company (Limited).

These works, so called in honor of the late president of the Pennsylvania Railroad Company, are among the most recently constructed American Bessemer establishments. They comprise 106 acres of ground lying at Bessemer station, 11 miles east of Pittsburgh, between the main line of the Pennsylvania railroad and the Monongahela river (slack-water navigation), upon which there is a frontage of 3,300 feet. This ground is a part of the historic Braddock's field. The Pittsburgh division of the Baltimore and Ohio railroad passes through the property, and upon the high and ample portion of it lying between these railroads, the existing works are built. There is room for indefinite extension. By means of these railroads the works are directly connected with the Eastern, Western and Southern railway systems; and by means of the river, with the

coal-fields of the Connellsville region, and with the Ohio and Mississippi navigation.

The Bessemer plant, like all the American plants, involves the principles of construction and arrangement which were fully set forth in the description of the Vulcan Iron Company's steel works—the first of this series of articles. The statistics of production hereinafter given fully prove the capacity of this type of plant for the economical making of a large product. The converting machinery comprises three cupolas of 5 ft. internal diameter, and 14 ft. in height to the charging door; four spiegel cupolas of 2 ft. internal diameter; two tipping cupola ladles of 12-ton capacity, resting upon scales; two 6-ton converters, 6 ft. in internal diameter by 15 ft. in height; also ladles, bottom casting flasks, steam ingot-compressing apparatus, and the following hydraulic machinery.

1124 *Engineering.*

Vol. 30, page 95. July 30, 1880.

Barrow Hematite Iron & Steel Works.

"When the Iron and Steel Institute held their meeting at Barrow in 1874, we gave a lengthened account of these works (see Engineering, vol. 18, page 228). During the past six years, although the general plan remains the same, a large number of improvements have been made, and we therefore propose to supplement our previous article, so that our readers may have a more correct impression of the works, as they will be seen next week during the visit of the members of the Institute of Mechanical Engineers. * * *

At the iron works two considerable alterations have been made. The long row of fourteen blast furnaces had been reduced to twelve, and changes have been necessitated by the introduction of the 'direct process,' which involves the transportation of the iron molten from the blast furnace direct to the Bessemer converter. * * *

To carry out the direct process a siding has been constructed at the iron works in a cutting about 9 feet deep at the base of the line of the pig beds, inside the boundary wall. Into this two or three wagons are shunted at a time; they are of simple design, and specially arranged for the transportation of the molten metal; they each have in the center a ladle capable of carrying, if necessary, 11 tons or 12 tons of metal, though about 8 tons is the usual quantity. Formerly the ladles were placed at one end of the wagon, and were balanced by weights at the other end; but the new design works better, and is, of course, much lighter. The metal is run from the furnace the whole length of the pig bed down an ordinary channel in the sand, to a point where there is a movable spout, over which the molten iron falls into the ladle. If desired the whole charge need not be taken from one furnace alone, but a mixture of
1125 the products of different furnaces may be made. When sufficient iron is in the ladle the channel is stopped, and the rest of the cast is allowed to run in the usual way for the manufacture of pigs. No difficulty is experienced as to the chilling of

the molten metal; a small quantity of coal dust is sprinkled over the top, and the iron arrives at the steel works without any injurious loss of temperature. From the twelve furnaces the molten iron travels about a mile to the steel works, having to run to a junction, but from the two isolated furnaces the distance traversed is nearly two miles, and even in this length of journey no inconvenience has been experienced by the metal becoming cold.

It will be remembered that one of the most interesting discussions at the 1874 meeting of the Iron and Steel Institute was in reference to the practicability of transporting the molten iron from the blast furnaces to the Bessemer converter. The system had been even then tried, and had succeeded, on the continent, but in 1874 it was believed that, at least in England, the process would be too hazardous. Even if the practical mechanical difficulties could be overcome at those works originally designed for the old system, it was considered by most of the steel-makers that it would be impossible to obtain constant results from the blast furnace, and to make steel from iron, the nature of which was unknown, would be too dangerous a leap in the dark. Within the last half dozen years, and within a mile of the scene of the discussion, the question has been practically settled on a scale of the greatest magnitude. Thirteen of the Barrow furnaces are now in blast, and the yield is over 6,000 tons per week; of this quantity more than one-third goes to the steel works, and now none is in the form of pigs, unless to fulfill some order where reheated iron may have been stipulated. In the regular working it is known beforehand what will be the quality of the iron, and there has been no difficulty in this respect. Doubtless the large number of furnaces at Barrow is a great advantage, as if any of them
1126 are temporarily not in good working order, the iron for the converters can be obtained equally well from other furnaces. It is quite possible that a small works, with not more than two blast furnaces, more or less serious inconvenience might arise by the temporary derangement of one or both furnaces, which could only be effectually guarded against by heavy stocks of pig iron, and much extra plant in cupolas, &c., which would mean a large amount of capital usually lying idle."

Engineering.

Colburn, London, 1873. Vol. XV, page- 113 & 114.

Bessemer Machinery.

By Alex. L. Holley, C. E.

(Concluded from Vol. XIV, page 417).

In the melting department some interesting and important changes have been made. The reverberatory furnace was, until recently, employed abroad for melting the principal charge, and is still used here and abroad for the spiegeleisen charge, because, as this is small and often has to be held for some time after melting,

the flame of the reverberatory constantly playing over it prevents its chilling. The very oxidisable manganese in the spiegeleisen is also more affected by the blast of the cupola than by the comparatively neutral flame of the reverberatory.

In the older form of air furnace (Fig. 7), the flame and any free air it may contain, are drawn from the fire-box A, along the roof of the furnace, and do not come into very direct contact with the metal lying at B; hence this form is best employed for melting the spiegeleisen. Fig. 8 shows a later form of furnace, which melts faster because the flame is thrown directly upon the metal lying at B; but it also oxidizes the metal more rapidly. It was first employed for melting the principal charge, but as it required
1127 three hours and two and a half tons of coal to bring down 5 tons of iron, it was early abandoned here for the cupola, which melts a 6-ton charge in less than one hour with 1 ton of coal.

Adapting the cupola to the Bessemer manufacture has, however, required some costly experimenting. What was considered the best foundry cupola—Mackensie's (Fig. 9)—was first employed; but it would only melt 20 or 30 tons. The shallow bottom then filled with slag, which choked the tuyeres and scaffolded above them. The present cupola (Fig. 10) melts 100 tons in 18 to 20 hours.

The foundry cupola is made large enough to melt what is required in two or three hours; the hearth is left shallow to take the least amount of fuel, for the bed of coal must reach above the tuyeres, however little iron is melted. And the day's work is over before slag accumulates to any embarrassing extent. But the Bessemer cupola must deliver six tons an hour, at the highest attainable temperature, for a whole day and night. There must be a deep hearth or receptacle for slag under the tuyeres, and an upper tapping hole by which the slag may be worked off as in a blast furnace. The tuyere area must be excessively large to insure ample air admission in case of partial chilling at any point; and the size, shape and arrangement of tuyeres must be such that they can be conveniently got at, cleaned and changed without stopping the operation.

A cupola for a 5-ton plant is of 5 ft. internal diameter and 14 ft. high; it has six oval tuyeres of 5 and 8 in. diameter. The boshes, so prominent in the Mackensie cupola, are reduced to prevent scaffolding. The Mackensie annular tuyere, however valuable in foundry practice, is not adapted to long-continued heats, because it cannot be conveniently cleaned from without while working.

After the last charge is tapped out, the Bessemer cupola bottom is dropped, in the usual manner, to discharge the remaining debris.

1128 The most trustworthy cupola-blower, for the pressure here required—not less than a pound per inch—is undoubtedly a light reciprocating engine, like a blast-furnace blowing machine. To give the required volume—6,000 cubic feet per minute—such an engine is rather costly. After much unsatisfactory experimenting with rotary pressure blowers, several American works have adopted

the comparatively cheap Sturtevant high-speed fan-blower, with marked success.

Interposing ladles between the cupolas and vessels, is important in many respects. 1st. The cupola cannot be so economically and regularly worked if its hearth has to fill up with the whole 12,000-pound charge of iron every hour. 2nd. The weight of the charges should be somewhat uniform to promote uniformity of the accuracy of blowing, and to recarburise with a fixed percentage of spiegeleisen. This can only be accomplished by weighing the charge between the cupola and the vessel; and the ladles are placed on scales for this purpose. 3rd. Several charges are often run into the ladles when the converting department is not ready for them; otherwise the cupola would have to be dumped, and part of a day's work lost.

1129 *Engineering.*

An illustrated weekly journal.

Edited by W. H. Maw and J. Dredge.

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London.

Pages 416 and 417.

*Bessemer Machinery.**

By Alex. L. Holley, C. E.

A very large and regular product is essential to commercial success. The same engine and boiler capacity, the same vessels and accessories, the same quality and nearly the same extent of hydraulic machinery, melting apparatus, and buildings are required—in all, say, 200,000 dollars' worth of plant—to make six 5-ton heats per day, as to make sixteen 5-ton heats per day. Six heats was the maximum work in England three or four years ago, and still is in some foreign works, ten or twelve being the average abroad, while eighteen to twenty-four heats are the standard practice in America. This additional work, got out of nearly the same capital, is the result of these mechanical refinements.

1130 *Engineering.*

Colburn. 1875. Vol. XX. London. Article from page 147. Aug. 20, 1875.

The Edgar Thomson Steel Works.

We have frequently had occasion to refer in this journal to the works of the Edgar Thomson Steel Company, Limited, and as these works are now completed some general particulars will be of interest. The works, which represent the latest and best American

* A lecture delivered before the students of the Stevens Institute of Technology

practice, are situated near the village of Braddock, eleven miles east of Pittsburg, on the main line of the Pennsylvania railroad, and on the Connellsville division of the Baltimore and Ohio railroad. The distances by rail from Pittsburg to various important points, are as follows: To Philadelphia, 355; to New York, 440; to Boston, 636; to Baltimore, 330; to Cleveland, 150; to Chicago, 468; to Cincinnati, 313; and to St. Louis, 619 miles.

A connection has already been made with the Pennsylvania railroad, with both high and low level tracks in the yards of the works. This is to be extended to the Baltimore and Ohio railroad during the present season. A bridge across the Monongahela river, a mile above the works, which is far advanced towards completion, will give immediate connection by the Pan Handle line with the entire railway system west and southwest, and eventually by the Virginia and Charleston railroad, with the whole Upper Monongahela valley.

The property of the company has a front of 3,300 ft. on the slack-water level of the Monongahela river, and hence an outlet to the whole Ohio and Mississippi system of navigation. The property is divided into three parts. The strip lying between the Pennsylvania railroad and the county road being 300 ft. by 1,800 ft. That lying between the county road and the Baltimore and Ohio railroad being 600 ft. by 1,500 ft., and that lying next to the river, a
1131 part of which is occasionally overflowed, being 1,000 ft. by 3,000 ft. The whole comprises about 106 acres.

The buildings now erected, are as follows: Cupola-house, 107 ft. long, 44 ft. wide, and 46 ft. high. Converting-house, 129 ft. long, 84 ft. wide and 30 ft. high. House for blowing engines, 54 ft. long, 48 ft. wide and 36 ft. high. Boiler-house, 178 ft. long, 40 ft. wide and 18 ft. high. Producer-house, 90 ft. long, 46 ft. wide and 26 ft. high. Rail mill, 380 ft. long, 100 ft. wide and 25 ft. high, with a wing 100 ft. long, 35 ft. wide and 17 ft. high. Office and shop building, 200 ft. long, 60 ft. wide and 18 ft. high. A coal and iron house, 40 ft. long, 20 ft. wide and 10 ft. high. The producer-house and rail mill have iron side columns with timber side framing. All the others are wholly of brick, and all, without exception, have iron roof frames and coverings.

The converting machinery comprises three cupolas, 5 ft. clear diameter, and 40 ft. high; four spiegel cupolas, 2 ft. in diameter and 40 ft. high; two 12-ton cupola ladles upon scales; two 5-ton converters, 6 ft. clear diameter by 15 ft. high. Twelve crane ladles for casting, and a full equipment of ingot moulds and flasks for bottom casting. Ample oven capacity is provided for drying spare bottoms for the converters, the flasks and ladle stoppers. A crusher and a mixing mill of approved patterns are placed in the cupola-house, in which also is ample room for storage of refractory materials required for immediate use.

Experience in other works of a similar character has shown that a product may fairly be looked for in each 24 hours, of 200 tons of ingots, and 225 tons of rails, if rolled in double lengths, and of 200 tons if rolled in single lengths.

The works were expected to be in operation early in the present month, the board of managers being Mr. D. McCandless, chairman; Mr. John Scott, Mr. T. M. Carnegie, Mr. D. A. Stewart, Mr.
1132 William P. Shinn, secretary and treasurer. The engineers' department comprises Mr. A. L. Holley, chief engineer; Mr. P. Barnes, resident engineer, and Mr. John C. Lewis, civil engineer, and as we stated at the commencement of this notice, the whole arrangements of the works are founded on the latest and best practice.

Steel:

Its history, manufacture, properties, and uses.

Jeans.

The Rhymney steel works.—These are among the latest, as the Barrow were among the earliest works of the kind erected in the United Kingdom. They are thus described by Mr. Richard Laybourne, M. Inst. C. E., past president of the South Wales Institute of Mining Engineers.*

"The plant, having been erected for the purpose of converting old iron works, and adapting them to the manufacture of steel, the arrangement was somewhat controlled by the situation of the blast furnaces it was intended to use for the process, and also by the extent of ground available. It was erected for the purpose of making steel by the direct process, that is by taking the molten iron direct from the blast furnaces and submitting it to the process of conversion on the Bessemer system, instead of running it into pigs and then remelting them in an air furnace or cupola, the method until very recently most usually adopted.

"In laying out the works it was considered desirable to take the opportunity of getting rid of the tramways, which covered the ground like a network and were worked by horses, substituting in their place ordinary narrow-gauge (4 feet 8½ inches) railways, to be worked exclusively by locomotive engines. On examination the ground was found to be an old cinder tip, upon a shelving sub stratum of retentive clay with boulders. The site was effectively drained by a main culvert to the river, with branches; these
1133 are constructed of the egg-shaped section, of bricks laid in mortar made with hydraulic lime. Above these drains are culverts or subways, in which are placed the hydraulic and blast pipes.

"More uniform results being obtained by mixing the produce of two or more blast furnaces, this plan is followed here, with the means of taking a further supply of iron when required from the cupolas (two in number), which are situated alongside the subway leading from the furnaces to the steel works; they are used for remelting the iron made and run into pigs on Sundays and at such other times as the steel works may not be in operation, care being taken to use such iron in the cupolas as will correct any irregularity

*Transactions of South Wales Institute of Engineers, session 1877-'78.

in the iron taken from the blast furnaces, and thus secure the desired regularity in quality.

"The iron is run from the furnace into a ladle standing on a railway in the subway; it is drawn by a small locomotive engine up a gradient of 1 in 50. The carriage and ladle now stand on the floor of the converter-house, and as they are still below the level of the converters, the ladle full of metal is lifted from its carriage by a 12-ton hydraulic crane and poured direct into the converter, which is then turned up and the blow commences; this lasts from 15 to 20 minutes, with a blast pressure of 25 lbs. upon the square inch. After the blow the same crane conveys the spiegeleisen direct from the cupola to the converter. An empty casting ladle suspended on the other side of this crane is now swung round to receive the steel and transfers it to the centre casting crane, which is then turned towards the pit, leaving the charging crane and converters clear from obstruction and at liberty for the next blow, which can commence at once while the casting is being proceeded with."

1134 E. Sz. 7, 10, '96.

Stahl und Eisen.

V. Jahrgang, page 26, January, 1885.

Small Bessemer Operation in Combination with Larger Blast Furnaces.

(Drawing on plate III.)

After the publication of my article in Stahl und Eisen, No. 9 of last year, about the "Arrangement of Bessemer and Thomas furnaces for small operation" the thought has been extensively expressed by experts, that there would be difficulties connected with removing small quantities of iron from large blast furnaces at short intervals. Recognizing these difficulties entirely and apprehending that small quantities of iron taken directly from the blast furnace always get too cold, I take the liberty of making the proposal, to add to the blast furnace one or if necessary two reverberatory furnaces, so that the removals could be made entirely independent of the Bessemer business, at longer intervals, and to correspond with the most advantageous operation of the blast furnace. The iron would then first run into the reverberatory furnaces, that form in a measure reservoirs for the liquid iron, but at the same time would allow not only a greater amount of heat to be imparted to the molten iron but also to melt in other kinds of iron with it.

Wetter (weather) in December, 1884.

ALFRED TRAPPEN.

1135 *American Society of Mechanical Engineers.*

Transactions, vol. 6, New York city, 1885.

CLIV.

An Account of the Experimental Steel Works at Wyandotte, Michigan.

By W. F. Durfee, Bridgeport, Conn.

In the month of June, 1862, the writer of this paper was invited by the late Captain E. B. Ward, of Detroit, to design and superintend the construction and working of the machinery and apparatus necessary to test, by an experiment on a large scale, the merits of a process for the production of steel invented by William Kelly, of Eddyville, Kentucky.

At the time of which I speak the late Z. S. Durfee, who was associated with Captain Ward in the new enterprise, had been for some months in England, endeavoring to purchase certain United States patents that had been secured by Mr. (now Sir) Henry Bessemer for a process essentially the same as that of Mr. Kelly, and for a time it was believed that he would be successful in so doing. I mention this at the outset of my paper, as it explains the adoption of certain forms of apparatus, invented by Bessemer, in the Wyandotte experimental works. In discussing with Captain Ward the general scheme for the proposed experiment, it was determined to build an engine of sufficient power and blowing capacity for use in an establishment for producing steel on a commercial scale, should the results in the experimental works justify such an enterprise, and a similar conclusion was arrived at with respect to the size and general character of the converting vessel. As to the rest of the apparatus, it was decided to design it without reference to any possibility of its use in another work, but as cheaply and as simply as it could be made for the purpose of the experiment
1136 only; and it was further determined to erect the experimental plant adjacent to, and partly in, the buildings of the Eureka furnace at Wyandotte, some ten miles below Detroit, on the Detroit river, where Captain Ward had extensive rolling mills. It was also determined that the metal for the experiment should be taken direct from the blast furnace, and that the spiegeleisen should be melted in crucibles.

The plan (Fig. 3) shows the general features of the arrangement adopted, save that over the center of the casting pit was a single-track traveling hoist for handling the ingots and moulds. This hoist was operated by a winch located at W. It was adopted not as the best, but as the only available expedient for the purpose, the space allotted me in the casting-house and the construction of the house itself not permitting the use of a crane of ordinary form.

The reverberatory furnace for melting pig iron was not included in my original programme of procedure, but was erected in the summer of 1864, for reasons that will be given in another place.

Returning from this digression and continuing the description

of the works, Fig. 4 is a view of the machinery as it appeared to a person standing in the pulpit (Fig. 3), and looking toward the converter, V.

The lifting of the fluid cast iron delivered by a runner from the blast furnace into the hoisting ladle H (Fig. 4) placed upon the platform of the scales A, and the pouring of it into the converter, was accomplished as follows:

The carriage of the crane was run to the left-hand end of the girders on which it was placed, and the hooks on the double chain C were attached to the trunnions of the hoisting ladle, and the hook on the single chain was connected with the eye seen (in Fig. 4) on the left-hand side of its bottom. The converter having been turned into a proper position to receive the metal, the hoisting gear was put in action and the ladle H (Fig. 4) with its contents was raised and carried to the right until the end of its spout was over
1137 the mouth of the converter. The raising of the ladle was then stopped, and it was turned upon its trunnions by continuing the hoisting on the chain O, until all the metal which it contained had been discharged into the converter.

American Society of Mechanical Engineers.

Transactions, Vol. 6. New York city, 1885.

CLV.

The Original Bessemer Steel Plant at Troy.

By Robert W. Hunt, Troy, N. Y.

In calling the attention of the society to a short description of the original Bessemer steel plant at Troy, N. Y., I cannot hope to present matter of much value; and can only crave your indulgence while placing on record the plans and practice of the first Bessemer plant that made a commercial success in America. My paper, taken in connection with that of Mr. Wm. F. Durfee on the Wyandotte works, may possess some additional interest by drawing your attention to the wonderful progress which has been made in this march of metallurgy during the last nineteen years.

As is well known, there were rival patents bearing upon the pneumatic process. The Kelley and Mushet patents were owned by the Kelley Process Co., who built the Wyandotte works; and the various Bessemer patents belonged to Messrs. Winslow, Griswold & Holley, the latter firm erecting the Troy plant. Of course this state of things caused great jealousy and rivalry. Mr. Durfee succeeded in starting his plant a few months before his Troy rival, and hence to him belongs the honor of having made the first heat of Bessemer steel blown in this country. Alexander L. Holley commenced the erection of the Troy works immediately upon his return from England in the spring of 1864, and made the
1138 first conversion of steel on February 16th, 1865. From the start, complete records of the works have been kept, and hence I

am enabled to present the particulars of their early experience. But before so doing let me call your attention to the plate, Fig. 16, showing the arrangement of the plant. Its location was determined by the existence of a water power and wheel which had been used to run a grist mill. This opportunity for cheap power was too good to be neglected; and every other consideration sank into oblivion. Of how well this rewarded the owners, you can judge by the detailed history which follows:

Two blowing cylinders, "48 x 48," were attached to this old wheel, and the rest of the plant placed in a building 64′ x 41′, 8″, built for the purpose. The pig iron was melted in the reverberatory furnace J, having a bed 7′ long by 4′ 9″ wide, from which it was run through a gutter built in the floor to the wrought-iron runner F, and through it into the wrought-iron converter B, which was of course turned down to receive it. The runner F traveled on the rail Y, at its higher end and on a corresponding rail, to which its supporting road was attached, at the lower or converter end, so that after the blow was finished it could be pushed over against the wall of the building, and hence out of the way. A represents a brick stack with a brick hood, which carries off the flame of the conversions. The recarbonizing metal was melted in the furnace R, which is shown by the dotted lines and which worked into the stack M, in common with the furnace J. The resulting metal from the conversion was poured into the ladle E, which was supported by the cast-iron ram or crane D. This ram was controlled by attaching the chain of the wooden hand crane C, to it at the hook V, and it was so swung over the moulds set in the pit P. These molds and their ingots were subsequently taken from the pit by the crane C, and loaded on a car standing on the railroad track shown. The vessel was rotated by decidedly simple apparatus shown at U, which depended upon intelligent labor for its power.

1139 Such was the original Troy two-ton plant. And it is not now surprising that many difficulties were encountered in its management. Mr. Holly's mind was soon impressed with the advantages of melting in a cupola and one was erected. This was built as shown by K. It was provided with duplicate bottom sections. The extra one being pushed to one side, as shown by X. He also advanced beyond the English method by placing the accumulating ladle I, resting on scales in front of the cupola. G is the wrought-iron runner conveying the metal to the runner F. When the cupola practice was adopted, the spiegel furnace R was torn down and the furnace J converted in one for melting the recarbonizer which was conveyed through the cast-iron gutter H. The cupola bottoms were raised and lowered by the screw L. O was an oven for drying stoppers, and T its chimney.

While we smile over these records of a past, that to some of us seem so long ago—yet in time is but as yesterday—let us realize what these trials meant to those conducting them. Let us not overlook their earnest endeavors, their high hopes, many disappointments, but never-failing courage. Strong faith was required, both by the capitalist and the engineer. Probaby no industry ever made

such gigantic strides, attained such advancement in the same number of years, as the Bessemer process in America. But the fire that burnt away its crudities also consumed great spirits. The bold investor, E. B. Ward, the cultivated Z. S. Durfee, the perfect gentleman, the constant patriot, John A. Griswold, have passed away, while to those of us who have been in the thickest of the fight comes more closely the death of that daring engineer, always advancing, ever right, warm, uncompromising friend, George Fritz; and saddest of all, the loss of him whose hand recorded most of that which I have presented to you, records of the actual wearing away of his great heart. Applied science triumphed, but Alexander Lyman Holley died.

1140 *Transactions of the American Institute of Mining Engineers.*

Vol. V, May, 1876, to February, 1877, page 201.

A History of the Bessemer Manufacture in America.

By Robert W. Hunt, general superintendent, Albany and Rensselaer Iron and Steel Company, Troy, N. Y.

The memorable features of American history have been making fast during the last century, and notably so since 1860; and they are by no means confined to political or to any one branch of scientific development. Of all the industrial arts, none show a greater change or a mightier progress than the Bessemer manufacture. And this year, while we are celebrating the first centennial of our national life, we can also celebrate the first decennial of American Bessemer practice. While not forgetting or undervaluing what has been done in other countries, I have thought that a brief history of the introduction and development of the pneumatic or Bessemer process in America would be of interest.

In 1863 the Kelly Pneumatic Process Company was formed and an arrangement entered into with William Kelly, who had taken out letters patent of the United States, Nos. 16444; 17628, reissued as 505; 18910, dated January 10th, 1857; June 23rd, 1857; November 3rd, 1857, and December 22nd, 1857, respectively. This association was composed of the Cambria Iron Company, E. B. Ward, Park Brothers & Co., Lyon, Shorb & Co., Z. S. Durfee, and, later, Chouteau, Harrison & Valle joined the combination. Not satisfied with possessing the control of the Kelley patent, they sent Mr. Z. S. Durfee to England, to secure for this country Mushet's patent on recarburization, No. 17389, dated May 26th, 1857, the same having been taken out in England on September 22nd, 1856. In this Mr. Durfee was successful.

1141 Previous to the application of William Kelly for a patent, Henry Bessemer, of England, had taken out patents, dated February 12th, 1856, and August 25th, 1856, in this country. Kelly claimed priority in the discovery of the principles of the process, and the Patent Office allowed his claim by granting him his patents.

In the autumn of 1862, Mr. Alexander L. Holley, while in England, was impressed with the importance of Mr. Bessemer's invention, and so fully foresaw its future, that, upon his return to the United States, he induced Messrs. John A. Griswold and John F. Winslow, of Troy, New York, to join him in endeavoring to possess Bessemer's American patents. Mr. Holley returned to England in the summer of 1863, but not until the spring of 1864 did he succeed in purchasing for Messrs. Winslow, Griswold and Holley the desired rights.

Thus, at about the same time, there were two separate and distinct organizations seeking to control the future of the then undeveloped industry. While Mr. Durfee was abroad his company determined to erect experimental works at Wyandotte, Michigan, (where one of its members, Captain E. B. Ward, owned extensive iron works), with the view of testing the adaptability of American irons to the new process. Mr. William F. Durfee undertook the erection of the plant, and located it in the casting-house of the Eureka blast furnace, intending to take the metal direct from the furnace. He put in a 2½-ton vessel with a long narrow casting pit, and arranged a system of rotary steam-engines to hoist and pour the melted iron into the converter, and to rotate the latter. As Mr. Durfee was instructed to avoid as far as possible Bessemer's mechanical patents, he was very much hampered in designing his plans. But it was in these works, in the fall of 1864, under the direction of Mr. William F. Durfee, that the first pneumatic or Bessemer steel was made in America.

1142 Mr. Z. S. Durfee brought with him, on his return from England, Mr. Lewellen M. Hart, who had acquired some experience in the business at the works of Messrs. Petin, Gaudet & Co. in France. Upon the arrival of Mr. Hart at Wyandotte, he decided to build a reverberatory furnace for the purpose of melting the charges of iron, so as to be able to use a mixture of English and American irons, and it was from metal melted in this furnace that all the steel made by him at Wyandotte was produced. The works remained under this gentleman's charge until the beginning of 1865, when he severed his connection and went to Troy, New York, entering the service of Messrs. Winslow, Griswold & Holley. He subsequently went to the Pennsylvania steel works, at Harrisburg, Pa., and afterwards left their employ to engage in other business in Philadelphia, where he died.

In March, 1865, Mr. Ignatius Hahn assumed charge of the Wyandotte works. This gentleman had lately arrived from Prussia, where he had been connected with the works of Krupp, at Essen. He conducted the works until July 4th, 1865, when he resigned his position. As Mr. Hahn's retirement left the company without any practical steel-maker, and the works had thus far been conducted on an experimental basis, the proprietors determined upon making the most hazardous experiment of all, and put them in charge of the writer, who had gone there a few weeks before, in the interest of the Cambria Iron Company. In accordance with this arrange-

ment the writer made his first "blow," and, by some strange fatality, happened to "turn down" at just the right time.

In the fall of 1865 the reverberatory furnace was torn down, and thereafter, during the continuance of the works, the iron was taken directly from the blast furnace, excepting that which was sent to the works to be tried experimentally, and which was melted with anthracite coal in a McKensie cupola, this cupola having
1143 been put up by the writer during the summer of 1865. In October, 1865, the first heat of Bessemer steel made from Missouri Iron Mountain pig was blown by the writer, it having been melted in this cupola; the resulting steel was extremely satisfactory.

During Mr. Hahn's administration Mr. Z. S. Durfee made several attempts to convert iron melted in the small cupola of a foundry attached to the works, and located on the opposite side of the furnace casting house. But owing to the cupola being so distant and so small, thus requiring the iron to remain so long in the accumulating ladle, and then to be run so far in an open runner into another ladle, and to be hoisted and poured into the converter, the iron containing also a low percentage of silicon, each trial was a failure. But I believe this was the first attempt to utilize the cupola as a melting furnace for the Bessemer process. At all events, it certainly was the first time it was tried in America, and of its ultimate success Mr. Durfee was fully convinced. Mr. Holley must have been impres-ed at about the same time with the same idea, for the records of the Troy works show that on July 20th, 1865, the cupola was there used for the first time, and with complete success.

The writer remained in charge of these works until May 14th, 1866, when he turned them over to Mr. A. S. Aubrey and returned to the Cambria works, that company then intending to at once erect Bessemer works. During the year 1865 Captain Ward bought the works from the Kelley Process Company, and they were thereafter conducted entirely in his interest, and, after many alterations, finally abandoned in 1869.

Upon Mr. A. L. Holley's return from England, in the spring of 1864, — at once commenced the erection of a 2½-ton experimental plant at New York, for the firm of Winslow, Griswold & Holley, and started it February 16th, 1865. While at the Wyandotte works steel was made at an earlier date, the Troy establishment was the first to bring the process near to a commercial success. Not
1144 having been personally connected with these works during those early days, I cannot so fully realize the doubts and difficulties through which they passed, but I do know from the Wyandotte, to say nothing of any later experience, that it has required faith made perfect, to carry one through the sea which seemed to be bounded by no shores. As I have often expressed it, if we, knowing there was a way through all our troubles, felt so hopeless, what must have been Bessemer's pluck, to enable him to persevere through his difficulties, when the desired end was known only through faith.

But, before entering into chronological details of subsequent

works, I must here state, that, after building the first experimental plant at Troy, Mr. Holley seems to have at once broken loose from the restraints of his foreign experience, and to have been impressed with the capabilities of the new process. The result is that mainly through his inventions and modifications of the plant we, in America, are today enabled to stand at the head of the world in respect of the amount of product.'

In accordance, I presume, with these results, I find that the first conversion made at Troy was from Crown Point charcoal iron, the first at Wyandotte having been from Lake Superior charcoal, direct from the blast furnace. The success of the Troy works, whenever good metal was used, encouraged the proprietors to commence the erection of new works on a more extended scale, and early in 1867 Mr. Holley completed the new or 5-ton plant, Mr. John C. Thompson then being superintendent of manufacture. Mr. Holley at this date assumed personal charge of the Pennsylvania steel works, having previously furnished plans for the machinery, and Mr. Thompson soon after took charge of the Cleveland Rolling Mill Company's works. Mr. Z. S. Durfee then entered upon the management of the Troy works. He built the forge and made some alterations both in plant and details of manufacture. Among other things he adopted for the small or experimental plant the practice of
1145 melting the recarburizing metal in crucibles, and obtained most excellent results. At this time the capacity of the works was stated to be forty tons of ingots per day, but the records of the works fail to show any such actual results.

The works continued steadily running after being rebuilt, Mr. Holley relinquishing the management in 1871, but still retaining a connection as consulting engineer, which position he still holds. He was succeeded by Mr. Barney Mee, who died February 11th, 1872. His place was filled, for a short time, by Mr. John C. Thompson, who returned to the scenes of his first experiences, but his health failing the works were without a head until October 1st, 1873, when the writer assumed control. Mr. J. Wool Griswold has been in direct charge since May 1st, 1875. On March 1st, 1875, the firm style was changed to "The Albany and Renselaer Iron and Steel Company."

I must be permitted to mention, as an amusing incident and as showing how little we can foretell what time will bring forth, that in 1865, while connected with the Wyandotte works, I called, in passing through Troy, at the steel works and presented a letter of introduction to Mr. Holley, who, in the gracious manner of which he is so capable, most blandly, but equally firmly, declined letting me inside the works, and with the best grace possible under the circumstances I bowed myself out of his presence. Ten years later I am in charge of the works, proud to consider Mr. A. L. Holley my most intimate friend, and very careful to frequently remind him of our first interview. These works are now producing about 1,300 tons of ingots per week, which is sufficient to keep the rail mill running double turn; their largest month gave a yield of 5,498 gross tons.

The Pennsylvania steel works were the *the* third Bessemer works started in the United States. The company was organized under the presidency of S. M. Felton, Esq., and under the auspices of such prominent railroad men and engineers as the late J. Edgar
1146 Thomson, Nathaniel Thayer, M. W. Baldwin & Co., William Sellers & Co., Bement & Dougherty, R. P. Parrott, H. R. Worthington, Merrick & Sons, Morris, Tasker & Co., and others. Upon the first organization of the company Mr. William Butcher, of Sheffield, England, was elected as the engineer, and ground was broken, but, later, other arrangements were made, and the works were built upon plans furnished by Mr. A. L. Holley, and on January 1st, 1867, that gentleman severed his connection with the Troy works and, removing to Harrisburg, assumed entire charge of the construction, being assisted by Mr. H. S. Nourse. In June, 1867, the Bessemer works were first started, and have been ever since in constant operation. The rail mill of the company not then being completed, most of the ingots were rolled into rails at the Cambria iron works, Johnstown, Pennsylvania, this arrangement lasting until May, 1868. I find it stated, in an official publication of July 27th, 1868, that the "annual capacity of the present Bessemer plant (two 5 ton converters) is about 10,000 tons, and of the rail mill 30,000 tons. Additional converters will be erected from time to time." The time for such additions has not yet arrived, but the product has been increased fully five hundred per cent., the heaviest day's product up to date having been one day 281, week, 1,291, and month, 5,455 gross tons.

The writer had charge of the rolling, at Cambria, of the Pennsylvania Steel Company's steel, and well remembers with what proud satisfaction Mr. Holley visited Johnstown and proclaimed to us all, that at last his dream was realized; that the Pennsylvania works were making four conversions on each turn, or eight per day, producing forty tons of ingots. I presume that "official document" was inspired just about this time. In May, 1868, the rail mill was completed, and since then the company have taken care of their product at their own works. At first they pursued the same plan (rolling 8¼-inch ingots with a reheat) under which their steel
1147 had been rolled at Cambria, but subsequently introduced hammering; two hammers have up the present time drawn the ingots into rail-blooms, but the company are now erecting a blooming mill constructed by Mr. James Moore at Bush Hill iron works, Philadelphia.

Upon Mr. Holley's relinquishing the management of these works, in 1868, he was succeeded by the joint management of Mr. Nourse and Mr. John B. Pearse. This arrangement in turn was succeeded by another, by which, in 1870, Mr. Pearse took charge of the company's business as general manager, Mr. Nourse remaining as superintendent. Mr. L. S. Bent is now in charge of the works.

The first ingots made at Harrisburg and sent to Johnstown to be put into rails, were drawn into blooms under a 5-ton hammer. A limited number were also hammered at the works of Seyfert, McManus & Co., Reading, and the blooms sent to Cambria. While

watching the behavior of the steel under the hammer, Mr. George Fritz, chief engineer of the Cambria works, became convinced that it was not the proper manner of treating the material, and he and Mr. Holley had many consultations on the subject. Mr. Fritz at once turned up a set of blooming rolls which he placed in a 21-inch rail train, and Mr. Holley caused 8¼-inch ingots to be cast and sent him. These were drawn to 6½ inches square, then recharged and wash-heated and then rolled into rails. So well did this work, that Mr. Holley adopted the system in the Pennsylvania Steel Company's rail mill, which he was then building. After many discussions and consultations he decided, on his return to Troy, to build the heavier blooming mill to which I have before referred.

The Freedom iron and steel works, near Lewistown, Mifflin county, Pa., were the fourth Bessemer works started in this country. They were organized under the presidency of Mr. John A. Wright, and absorbed the interests of the Logan Iron Company, which company had been successfully working for many years. Mr. Wright
1148 visited England, and made purchases of the most complete machinery there known, and with the exception of the blowing engine, which Messrs. I. P. Morris & Towne, of Philadelphia, built, the works may be said to have been of English construction and arrangement. The company intended to manufacture principally boiler plates and tires, but the plate mill, which was driven by a Ramsbottom reversing engine, was soon changed to a rail mill. The works were under the direction of Mr. R. H. Lee, and ran for about one year, when, owing principally to the unsuitableness of the company's irons for Bessemer steel, the works were stopped, and much of the machinery subsequently sold. Their first blow was made May 1st, 1868.

The Cleveland Rolling Mill Company's Bessemer works, situated at Newburgh, six miles from Cleveland, were the fifth works erected. These were built after the same general plans as the Pennsylvania works, but Mr. H. Gmelin, the engineer in charge of construction, made many modifications. This gentleman returned to Austria before the blowing in of the works, which task was assumed by Mr. John C. Thompson, he making the first blow on or about October 15th, 1868. Mr. Thompson soon resigned the charge, owing to failing health, and the works have since then been conducted by Mr. Chisholm. In a short time, a second pair of 5-ton vessels were erected, and all four remained in operation until 1875, when the later pair were removed to make way for Siemens-Martin furnaces, which are now running.

This company deserves credit for being the first parties in this country to make a commercial success of the application of Bessemer steel to wire, screws, and several other specialties.

The Cambria Iron Company, of Johnstown, Pa., were sixth parties to build Bessemer works, their first blow being made by the writer on July 10th, 1871. As stated, the Cambria Iron Company did not erect Bessemer works until after five other concerns had
1149 started theirs, but nevertheless they were the very first corporation to give encouragement to attempts to perfect the new

process. When Mr. Kelly turned his attention to endeavors to shorten the process of refining iron by blasts of air, he was part proprietor and manager of a blast furnace at Eddysville, Kentucky. As in the case of many another seeker after the unknown, he spent all of his own money, and seriously embarrassed himself It was about this time that Bessemer obtained his American patents. After filing his claims as the original discoverer, Mr. Kelly succeeded in interesting the Cambria Iron Company, and under its patronage he transferred his experiments to its works at Johnstown, in 1859, and there met with the usual number of encouraging failures.

The first Bessemer converter ever erected in America, was built at Cambria, by Mr. Kelly, and still remains there, a cherished relic. It was calculated to convert about half a ton of metal, and received its blast from the foundry blowing engine. But I never heard even a tradition of a perfect conversion made in this vessel. Still the Cambria Company, and more particularly its general manager, the Hon. Daniel J. Morrell, were impressed with the possibility of success, and when the Kelly Process Association was organized, the Cambria Company was among the most earnest members. But the conservatism of other members of the company prevailed, and they did not complete their Bessemer works until 1871.

Their chief engineer, George Fritz, had been personally familiar with all of Mr. Kelly's experiments, and had closely watched the progress of the process as developed by Bessemer and others, and during the time the steel made at the Pennsylvania steel works was rolled at Cambria, he had abundant opportunities of studying the manufacture in its various mechanical details, and fully realized the advantages of the innovations introduced in the arrangement and details of Bessemer plant, by Mr. Holley. These two gentle-
1150 men had been thrown, during this time, into the closest personal intercourse, and while Mr. Fritz was only too happy to assist Mr. Holley with his advice and large experience in perfecting the plans of the rail mill for the Pennsylvania works, he was equally willing to avail himself of the latter's experience and advice in arranging his plans for the Cambria-Bessemer plant.

But George Fritz could not blindly copy, and while cheerfully acknowledging everything taken from Mr. Holley, he introduced many new ideas in his arrangement of plant. He built vertical, disconnected blowing engines, and arranged his converting building under one roof, without any dividing wall between the melting and casting houses. And when he came to the blooming mill, he introduced the entirely new features of driven rollers in the tables, and a hydraulic pusher for turning over and moving the ingots on the tables. These two features constitute the Fritz blooming-mill patent, now used by most of the Bessemer works of this country. The merits of rolling as compared with hammering had been fully discussed between Mr. Fritz and Mr. Holley, and they had, at various times, gone over the numerous details of a blooming mill, and Mr. Holley, as already stated, had built one at the Troy works. Mr. Fritz had availed himself of the benefit of the extensive knowledge and sound judgment of his brother, Mr. John Fritz, of Bethlehem,

Pa., and the result of all was the Johnstown blooming mill, which marked a new era in the Bessemer manufacture. While living to see many difficulties overcome, and great progress made, George Fritz died too soon, his country losing one of her noblest and ablest sons. He died August 5th, 1873.

The writer remained in charge of the works until September, 1873, when he went to Troy, and was succeeded by Mr. John E. Fry, who is still in charge. The greatest yield at these works has been as follows: March 21st, 1876, 297 gross tons in 24 hours; week ending May 20th, 1876, 1,475 gross tons; month ending March, 1876, 6,051 gross tons.

1151 The seventh works to go into operation, the Union Iron Company's, are owned by the same parties who control the Cleveland works, and are located at Bridgeport, or South Chicago, Ill. Their first blow was made on July 26th, 1871, and the works have been in almost constant operation ever since. They contained two 5-ton vessels, and the general arrangement is similar to the Newburg plant.

The North Chicago Rolling Mill Company, of Chicago, Ill., built and started the eighth Bessemer works. Captain E. B. Ward, of Detroit, was one of the heaviest owners in this company, and he, as before stated, had owned the Wyandotte works, and was fully convinced of the merits of the process, and while abandoning the last-named establishment, took steps to have a larger and more complete plant erected in Chicago in connection with the extensive iron works of the company. Mr. A. L. Holley was engaged to furnish the plans, and the works were erected under the direction of Mr. O. W. Potter, then the general superintendent of the company. Mr. Holley, profiting by the experience acquired in building the several other works with which he had been connected, and by the already advanced state of the art, introduced many improvements in the arrangement of this plant, and when completed it was undoubtedly the most perfect in existence. The first blow was made on April 10th, 1872, under the direction of Mr. Robert Forsythe, who had received his Bessemer education at the Troy works. This gentleman has ever since remained in charge of the converting works, and has been most eminently successful in his management. His works are today making the largest output of any in the world. The plant contains two 5-ton vessels. I might here say that while all the present American plants are said to consist of two 5-ton converters, the general practice is to convert nearer six tons in them. The ingots are bloomed in a three-high 30-inch mill with the Fritz tables.

1152 The records of the North Chicago Company show their largest product for 24 hours to have been 330¼ gross tons; for one week 1,583 gross tons; and for one month 6,457 gross tons.

The Joliet Iron and Steel Company, have rolling mills at Joliet, Ill., and blast furnaces at Chicago, determined to erect the ninth Bessemer plant in connection with their Joliet works. They purchased of the Freedom Steel Company their blowing engine, converters, hydraulic cranes, etc. Mr. Holley was engaged to furnish

the plans, and the works were built under his general direction, Mr. A. L. Rotham and Mr. P. Barnes being the engineers in direct charge. The converting plant consists of two 5-ton vessels, and the blooming train is similar to that of North Chicago. The general arrangement of the two converting works is also very similar. The first blow was made on March 13, 1873, under the direction of Mr. Dunning, who still remains in charge of the works. Their records show the greatest product in 24 hours to have been 350 gross tons; in one week 1,528 gross tons; and in one month 5,367 gross tons.

The tenth Bessemer plant was built by Mr. John Fritz for the Bethlehem Iron Company, of Bethlehem, Pa., of which he was, and is general superintendent and chief engineer, Mr. Holley being connected with him as consulting engineer. Mr. Fritz had studied the various American plants, and also visited England and the continent, and after mature deliberation concluded to take a new departure. He arranged his melting-house, engine-room, converting-room, blooming and rail mills, all in one grand building, under one roof, and without any partition walls. He placed his cupolas on the ground and hoisted the melted iron on a hydraulic lift, and then poured it into the converters. The spiegel is melted in a Siemens furnace, also on the ground floor, and the melted spiegel is also hoisted and poured into the vessels.

1153 The blooming train has the middle roll stationary, the same as the Cambria mill, the top and bottom rolls screwing up and down. Instead of depending upon friction to drive the rollers of the tables, Mr. Fritz put in a pair of small reversing engines. This feature has since been adopted in a method which dispenses with belts, by means of a direct connection of the engines with the table, as arranged by Mr. Holley, in several of the other works. The works made their first blow on October 4th, 1873, under the charge of Mr. Owen Leibert, who is still the superintendent. The highest product has been 264 gross tons in 24 hours; 1,340 gross tons in a week, and 5,282 gross tons in one month.

The Edgar Thomson Steel Company, Limited, of Pittsburgh, Pa., were the eleventh parties to enter the business, locating their works at McKinneys, now called Bessemer station, on the Pennsylvania railroad, about nine miles from Pittsburgh; Mr. Holley furnishing the plans and Mr. P. Barnes being the resident engineer, he having severed his connection with the Joliet works. In the fall of 1873, Mr. William R. Jones, who had been George Fritz's assistant at Cambria, became connected with the Edgar Thomson Company, and upon the starting of the works in August, 1875, assumed charge of them. He is now the general superintendent of the company. The largest product for 24 hours has been 265 gross tons; largest for a month's work, 5,403 gross tons.

In arranging these works, Mr. Holley made many improvements over any of his previous efforts, and assisted as he was, the works stand today as a fit monument of the progress of the Bessemer process in this country.

The twelfth and last works to start were those of the Lackawanna Iron and Coal Company of Scranton, Pa., being added to its already

large iron plant. The converting works were built by Mr. A. L. Rotham, Mr. Holley acting as consulting engineer. The former gentleman started the works on October 23d, 1875, and re-
1154 mained in charge until May, 1876, when he was succeeded by Mr. George F. Wilbur, who obtained his Bessemer experience at Johnstown, Pa. The blooming mill was built from Mr. Holley's plans, under the supervision of Mr. W. W. Scranton, the general superintendent of the company, and has all the late improvements.

The Vulcan Iron Company, of St. Louis, Mo., has their converting works and blooming mill nearly ready to start, they being an addition to its already large iron mill and extensive blast furnaces. Mr. Holley has furnished the plans and Mr. D. E. Garrison, the general manager of the company, has had immediate charge of the erection, Mr. John Hogan being his assistant. When these works start there will be in operation eleven 5-ton plants with 22 vessels, capable of turning out, in the aggregate, 550,000 gross tons of ingots per year.

Having enumerated the various Bessemer works according to the order in which they started, and in so doing having referred to the wonderful increase in product, it seems a fitting conclusion to briefly review the causes of such wonderful strides in capacity. As stated, after building the original experimental plant at Troy, Mr. A. L. Holley seems to have appreciated that the manufacture was capable of a development far beyond that which had been attained in those countries in which it was already considered a success.

Even if his mind did not fully realize this conclusion, his mechanical intuition was alive to the possibilities of improvement, and the result of his thought gave us the present accepted type of American Bessemer plant. He did away with the English deep pit and raised the vessels so as to get working space under them on the ground floor; he substituted top-supported hydraulic cranes for the more expensive counterweight English ones, and put three ingot cranes around the pit instead of two, and thereby obtained greater area of power. He changed the location of the vessels as related to the pit and melting-house. He modified the ladle
1155 crane, and worked all the cranes and the vessels from a single point; he substituted cupolas for reverberatory furnaces, and last, but by no means least, introduced the intermediate or accumulating ladle which is placed on scales, and thus insures accuracy of operation by rendering possible the weighing of each charge of melted iron, before pouring it into the converter. These points cover the radical features of his innovation. After building such a plant, he began to meet the difficulties of details in manufacture, among the most serious of which was the short duration of the vessel bottoms, and the time required to cool off the vessels to a point at which it was possible for workmen to enter and make new bottoms. After many experiments, the result was the Holley vessel bottom, which, either in its form as patented, or in a modification of it as now used in all American works, has rendered possible, as much as any other one thing, the present immense production.

Then he tried many forms of cupolas at Troy, adopting in the original plant a changeable bottom or section below the tuyeres, and developing this idea still further in the first 5-ton works; then later, at Harrisburg, assisting Mr. J. B. Pearse, the furnace was improved to a point which rendered these many bottoms unnecessary, chiefly by deepening the bottom and enlarging the tuyere area. Upon his rebuilding the Troy works after their destruction by fire, Mr. Holley put in the perfected cupolas. At this time the practice was to run a cupola for a turn's melting, which had reached eight heats or forty tons of steel, and then dropping its bottom. This was already an increase of one hundred per cent. over his boast about the same amount in twenty-four hours.

The Cambria works were now running, and Mr. Holley had become officially connected with them as consulting Bessemer engineer. Many discussions and consultations took place between Mr. George Fritz, Mr. Holley, and the writer, as to the possibility
1156 of increasing the product of the works. Among other things, tapping cinder from the cupolas was thought of, and decided upon. These works had already placed their turn's work at nine instead of eight heats. The Pennsylvania works under Mr. J. B. Pearse's management, followed with an increased production. The Cambria works applied the cinder tap, and the production went up to the unanticipated amount of thirty heats, or one hundred and fifty tons in twenty-four hours. Grand as we thought this, it is only about one-half of the present yield of each of several works. During all this time many details were modified, and as the new ways proved successful they were adopted in the regular practice. I think one thing which had a strong bearing on the increased production was the labor organization of the Cambria works. In compliance with the policy decided upon, I started the converting works without a single man who had ever seen even the outside of Bessemer works, and, with a very few exceptions, they were not even skilled rolling-mill men, but on the contrary were selected from intelligent laborers. The result was that we had willing pupils with no prejudices, and without any reminiscences of what they had done in the old country or at any other works. Of course when one works went ahead, the others had to follow. Mr. George Fritz was the embodiment of push, and with such men to call on as William R. Jones, J. E. Fry, Charles Kennedy, Alexander Hamilton, and D. N. Jones, his efforts were ably seconded, and Cambria for a long time maintained the lead.

Mr. Z. S. Durfee tried at Wyandotte to fill an ingot mould from the bottom, the steel being poured into the top of an adjoining mould. Upon taking charge of the works, I still further carried out this idea, and later Mr. John E. Fry and myself took out a patent on the process. At about the same time Mr. Holley, at Troy, was elaborating the same idea, and later, at Harrisburg, carried it much further and patented it. After the starting of the Cambria
1157 works, the process of bottom casting was fully gone into, and Mr. William R. Jones's improvements, since patented by him, rendered it a complete success. I know that some makers do

not fully acknowledge its merits, but it certainly has a right to rank among the prominent features of the American Bessemer practice.

While I am not able to mention all of the very many good things accomplished by the gentlemen at each and all the various works, I am, at the same time, well aware they have all done their share toward achieving the great end; and fortunately, their mutual relations have been so pleasant, that each one's experiences have been freely imparted to the others. This has done wonders to advance the science. But without one element, all skill and all mechanical talent would have been wasted, and with it nearly all things have been possible. That element has been, and is, "American push."

1158 *Founding of Metals.*

Pages 14-20.

Edward Kirk, Sharon, Pa., 1879.

Mixing and Melting Irons.

The foundryman cares little or nothing for a chemical analysis of iron, which merely shows the exact amount of different impurities it may contain; but the question that the foundryman asks is: What irons can I work, and how can I mix them so as to produce a good, clear, strong and cheap casting? This is a question that is almost impossible to answer, as it is impossible to give a complete vocabulary of all the impurities which iron may contain, with their effect upon the iron in different proportions as these proportions may be varied in remelting and produce different results, and even if it were possible, the foundryman does not wish to go to the trouble of making a chemical analysis of every lot of iron he gets in to ascertain its impurities and to keep track of how it may be mixed with some other lot of iron. Little can be told by looking at the iron in the pig whether it will run hard or soft when remelted and run into castings, or whether it will mix with another brand of iron. The foundryman, or an expert, may by actual test become acquainted with all the iron and ores used in a certain locality, and, by looking at the iron in the pig, tell very nearly what it will do when run into castings; but the best expert in the country can tell little or nothing about an iron that he has not been accustomed to working, and he will often be deceived in those he has been accustomed to, by merely looking at the iron in the pig. True, he may make a good guess, and he may tell whether an iron will run extremely hard or soft, but that is all that can be told by the looks of an iron in the pig.

It is impossible to qualify the various kinds of pig iron brought into the market by local terms and marks. It would not, after all,
1159 be of any use, because the furnacemen may change their ores or their mode of charging the stock, and change the product of the furnace from a No. 1 to a No. 2 or even No. 3 iron, which makes a great difference in its application in foundries; or a

rnace may change the quality of its iron without any change of
e ores, and without any apparent cause for the change in the
uality of iron. When operating at Lewisburg, Pa., last spring, I
ound a lot of pig iron that was used at the Dry Valley furnace, Pa.
his iron, when remelted and run into a cylinder head that was
early two inches thick, was so hard that it could not be drilled,
et the iron in the pig was of a dark gray color with a large open
rystal, and to all appearance was a No. 1 soft foundry iron. This
ron was made from the same ores that the furnace had been using
or years. In making a number 1 foundry iron no change had
een made in the mode of stocking the furnace, and there was no
pparent cause for the change in the quality of iron. This furnace,
fter it had been in blast for a short time, got to working so badly
hat it became necessary to blow it out. It was then found that
vhen putting the furnace in blast it had scaffold on one side, which
vas the cause of the hard iron. If a blast furnace with the fire only
n one side of it, will change the nature of the iron as this furnace
lid, then a cupola, with the fire or the blast all on one side of it, will
change the nature of iron when remelted. I have seen two cupolas
melting the same iron and one produced good, soft, strong castings,
nd the other produced hard or brittle castings. I have always
found that the cupola that produced the hard or brittle castings either
had the blast all on one side of it, or that the fire was not burnt up
evenly, and that the stock was not charged regularly.

Cast irons admit of a division into three classes and seven grades. The three classes are, the red-short, the cold-short, and the natural iron. The seven grades are the seven qualities or seven numbers of iron, as No. 1, No. 2, No. 3. Red-short iron is an iron that has no strength when red hot, and has a great deal of shrinkage. 1160 An extreme red-short iron will shrink as high as one-fourth of an inch to the foot. Red-short iron, when used for casting pipe on their end, will cause the body of the pipe to shrink down and leave the bowl of the pipe before the iron has thoroughly set; and when used in other castings, such as grate-bars, it will tear off and form cracks in the corners while hot; it will cause chill cracks on the tread of a car wheel, but they are not deep and do not injure the wheel. Red-short iron may be either hard or soft, and is liable to go to the extreme either way. It never breaks from shrinkage when cold.

Cold-short iron is an iron that has no strength when cold, and has very little shrinkage; it will resist very little strain, and if the patterns are the least bit out of proportion the casting will break from shrinkage after it is cold; it will cause stove plates to crack under the sprews. Cold-short iron may be either hard or soft, and is liable to go to the extreme either way; but it never breaks from shrinkage when hot.

Neutral iron is an iron between the extreme red-short and cold-short irons; it is made by mixing the red and cold short irons together. A neutral iron is the best iron for foundry purposes, and furnacemen who make a business of manufacturing foundry iron make it a point to mix their ores so as to make as near a neutral

iron as possible; yet in some localities one ore may be cheaper than another, and it may be used to excess, which may make an iron inclined to be either red-short or cold-short, yet not extreme either way. The foundrymen that is using three different brands of iron may find at times that he has two brands of iron inclined to be cold-short and one brand inclined to be red-short. If these three irons are mixed in equal proportions they will make a casting inclined to be extreme cold-short. Yet one-fourth of the two brands and one-half of the third brand, mixed together, may make a neutral iron and a good strong casting; or by leaving out one of the brands, and using one-half of each of the other two brands, the same re-
1161 sults may be attained. The only practical way to ascertain whether an iron is either red-short or cold-short is by actual tests in mixing and melting the iron in different proportions, and testing the strength and shrinkage. A neutral iron should not shrink more than one-eighth of an inch to the foot. Stove foundrymen should be careful to use as near a neutral iron as possible, and to change their brands of iron as little as possible, as the changes of iron often change the shrinkage, and will make trouble in mounting the stoves when much odd plate is kept on hand. When new brands of iron are introduced, test bars should be made to ascertain the shrinkage, and the different brands of iron should be varied so as to keep the shrinkage as near alike as possible.

The same theory may be followed in mixing irons to make a soft iron, thus: three brands of iron, mixed in equal proportions, may make a hard iron, while any two of the same brands, mixed in equal proportions, may make a soft iron. Tests were made last fall at Perry & Co.'s stove works in melting the three brands of iron, viz: Crane, Hudson and Jagger. These three irons were melted at the rate of 15 per cent. of Hudson to 85 per cent. of Crane and Jagger together. This mixture made a hard iron. One-third of each brand was then melted together and made a hard iron. One-half Hudson to one-fourth Crane and one-fourth Jagger were then tried, and the result was a hard iron. The Hudson and Crane were then tried together—one-half each—and made a good soft iron. The Hudson and Jagger were then tried together—one-half each—and made a hard iron. Thus, the Hudson would neutralize either the Crane or Jagger separately, but would not neutralize them when put together in any proportion.

Iron will combine with almost all of the sixty-four known elements, and these elements, combined with irons in different proportions, will destroy the affinity of one brand of iron for another, and foundrymen, in mixing their iron, will generally use equal proportions of
1162 all the brands of iron that they are using; thus, one-half, one-third, or one-fourth of each brand. If the castings come hard, they will reduce the No. 2 and increase the No. 1 iron, and I have often seen foundries that were using all No. 1 iron that were still troubled with hard iron. This was because they were using irons that had no affinity for each other, and would not unite so as to form a homogeneous iron; and throwing out the No. 2 iron gives only a temporary relief by the excess of carbon in the No. 1

iron, overcoming the non-affinity of the irons, and if the No. 1 iron happened to be a little poorer, one day or another, the iron was hard and uneven. I have often seen foundrymen that had one brand of iron in their yard that they had had on hand for years and could not use it, and perhaps the next foundryman that I would meet would be using that same brand of iron, and could not get along without it. This was because the one foundryman was using other iron as a mix that had an affinity for that particular brand of iron, or the two foundrymen might be using the same iron as a mix, and mixing them in different proportions, which produced different results. Two poor irons can often be mixed together so as to make a good iron, as is the case in mixing the extreme red-short and cold-short irons which form a neutral iron that is superior to either the red-short or cold-short irons for foundry purposes. In mixing irons I should recommend mixing them, and varying the mixture by the local brands or marks, and not by the numbers of the iron. To make a good iron, at least one-third of No. 2 iron should be used, and if all No. 2 irons can be used and make a soft iron, they will make a superior casting to all No. 1. In melting iron I should recommend melting it hot, and as fast as possible. A quantity of molten iron should be kept in the cupola or in a large ladle, so as to give the different brands of iron a chance to mix. In most all the foundries at Wheeling, West Va., the cupolas are never stopped in from the time the blast is put on until
1163 the bottom is dropped. A large ladle is set on trestles in front of the cupola, in such a manner that the iron can run into it from the cupola and be poured out into the smaller ladles at the same time. The iron is all run out of the cupola as fast as it is melted, and is mixed in the large ladle. I think this is a good way of mixing irons. See alloys.

Notes on the Construction of Ordnance, No. 21.

WASHINGTON, *May* 14, 1883.

Fabrication of cannon in Russia.

An outline by Lieut. Michel Levitsky, Russian navy.

Translated from the "Revue Universelle des Mines," by Capt. C. S. Smith and Lieut. Rogers Birnie, Ordnance Department, U. S. A.

Historical Sketch.

Page 14.

In casting a piece of considerable volume, like a cannon, the operation is commenced by placing a number of crucibles in each furnace, calculating their number from the ingots of metal necessary to fill the mold; the operation should, of course, be so conducted that all the crucibles may come to the melting point at the same time. The cast-iron molds employed for casting small pieces have very nearly the same form as the finished pieces themselves. It is not

the same, however, with cannon molds. The first form of a gun is nearly cylindrical, the interior walls of the mold being only slightly conical, from the sum-it to the base, in order to facilitate the withdrawing of the piece. The relation of the area of each section of the ingot to that of each section of the finished gun varies usually from 2 to 3. Previous to casting, the mold is heated by filling it with red-hot embers; the interior walls are rubbed with
1164 plumbago, or coated with whitewash or white clay, in order to render the surface smooth.

In castings of small dimensions the steel is turned directly into the mold from two crucibles, at first as rapidly as possible, afterwards slowly, but always continually. For large cannon, such as 12-inch guns, which weigh more than 85,800 lbs., the steel from the crucibles is run at first into a pool, from whence it afterwards flows in a continuous stream into the mold; after the mold is filled it is closed with a cast-iron cover loaded with weights, the pressure of which contributes to the production of a finer texture in the metal and a more compact grain. Sometimes, in order to effect a more uniform cooling, the free surface of the metal is covered with powdered and sifted clay, which evidently acts to retard the cooling of the upper layers, which, if not checked, often proves injurious to the homogeneity of the metal. The operation of cooling the ingot for a large cannon requires ordinarily from 23 to 25 minutes.

1165 *Report of Experiments on the Properties of Metals for Cannon and the Qualities of Cannon Powder, with an Account of the Fabrication and Trial of a 15-inch Gun.*

By Capt. T. J. Rodman, of the Ordinance Department, U. S. Army.

By authority of the Secretary of War.

Boston, Mass., Charles H. Crosby, 1862.

Pages 5, 6, 7, and 8.

August 21.—The mould for the solid gun was made and placed in the drying oven, and the first coat of clay put upon the core barrel for the hollow gun.

August 22.—The mould for the hollow gun was made and placed in the drying oven, and that for the solid gun pitted, and the metal for casting the guns charged as follows, viz:

Furnace No. 1 received	12,000 lbs.
Furnace No. 2 received	16,000 "
Furnace No. 3 received	18,000 "
Total charge for both guns	46,000 lbs.

Seven-ninths of the whole charge was Greenwood iron, and two-ninths Salisbury iron.

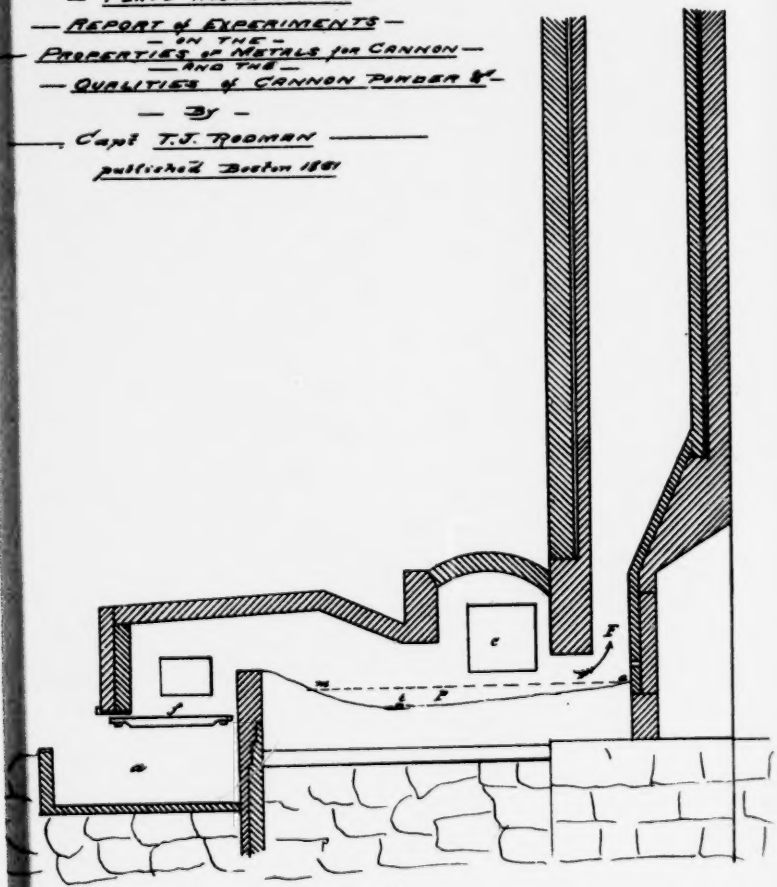
* * * * * * *

The preliminary melting was all done in one of the furnaces in

Carnegie Steel Co. v. Cambria Iron Co. } p. 1165a

PLATE I

— PLATE ACCOMPANYING —
— REPORT of EXPERIMENTS —
— ON THE —
— PROPERTIES of METALS for CANNON —
— AND THE —
— QUALITIES of CANNON POWDER &c —
— By —
— Capt T.J. RODMAN —
published Boston 1861



Scale 1/20th size

which the metal for casting the guns was melted. These furnaces are all what are termed air furnaces, having a sufficient height of chimney to create the requisite velocity of air through the fuel; which in all the meltings, both preliminary and for the guns, was bituminous coal of the best quality.

The furnaces are so constructed that the metal, as it melts, flows towards the flame.

The accompanying drawings—

(Here follows diagram marked p. 1165*a*.)

1166 (plate 1) shows a vertical longitudinal section of one of the furnaces, in which (*a*) is the ash-pit, (*f*) fuel chamber, (*p*) metal pool, (*t*) tap-hole, (*e*) charging door, and (F) the flue.

With a given charge of metal its treatment may be somewhat varied by the manner of dressing the bottom of the furnace, a broad, shallow pool exposing the iron more effectually to the action of the flame, and consequently making it hotter than when it is collected in a deep pool, with a small surface exposed to the flame.

The drawing represents the furnace as dressed for melting the iron from which the guns were cast; the line (*m e*) showing the surface of the metal when melted. The mean depth of the metal was about seven inches; that in No. 3 being something less, it being desirable that the iron in this furnace should be very hot, as it had a considerable distance to run—greater than that of either of the other furnaces. Furnaces Nos. 1 and 2 were charged up to their capacity. No. 3 could have received, perhaps, two tons more.

The flasks in which these guns were cast are in two parts, which open longitudinally, one-half of the gun, and one trunnion, being molded in each half of the flask.

Their cross-sections, when clamped together ready to receive the metal, is hexagonal, which gives an unequal thickness of sand around different parts of the same section of the gun, which, it is believed, is calculated to produce irregularity in the rate of cooling of the different wedges or staves of which the gun may be supposed to consist. And, as perfect homogeneity in each of the concentric cylinders of which the gun may be supposed to consist is believed to be of the utmost importance to its endurance, it would seem that a flask of circular cross-sections, which would give a uniform thickness of sand around every part of the same cross-section of the gun, would be more suitable for casting cannon.

1167 The casting for the hollow gun was cylindrical from about the middle of the chase to the muzzle, while that for the solid gun corresponded more nearly in shape with the finished gun.

Casting.

August 23, 1856.—Two 10-inch Columbiads were cast from the metal charged on the 22d, one, No. 331, was cast hollow and cooled from the interior by circulating water through the core barrel; and the other, No. 332, was cast solid and cooled from the exterior.

The furnaces were lighted at 10h. 50m. a. m. and Nos. 1 and 3 were tapped at 3h. 20m. p. m., the metal in all the furnaces having been 30 minutes in fusion. After the flow of metal from these furnaces had sufficiently decreased to admit of so doing, No. 2 was tapped and the flow of metal kept nearly uniform during the whole time of casting.

The metal from all the furnaces was received into one reservoir, from which it flowed in a single stream to a point equidistant from the two gun moulds; from this point it reached the mould for the solid gun in a single stream, and that for the hollow gun in two streams, one entering the mouth of the mould on each side of the core, the metal in both cases entering the mould directly and not through "side runners." The hollow gun mould was filled in 8½ minutes, and that for the solid gun in 12 minutes; the great heat of the metal preventing the workmen from so regulating its flow as to fill both moulds simultaneously.

Page 129.

The iron of which these guns were made entered the gun moulds identical in quality, the moulds being simultaneously filled from the same pool of melted iron.

1168 *Reports of Experiments on the* the *Strength and other Properties of Metals for Cannon.*

By officers of the Ordinance Department, U. S. Army.

By authority of the Secretary of War.

Philadelphia, Henry Carey Baird, successor to E. L. Carey, 1856.

Report of the Manufacture and Proof of 8-inch Columbiads, Cast at the Fort Pitt Works August 4th, 1849, by Messrs. Knap and Totten.

Page 169.

Two 8-inch Columbiads were cast at the same time from the same iron. One of them, No. 1, was cast solid in the usual manner; the other, No. 2, was cast, according to the plan invented by Lieutenant Rodman, on a hollow core, through which a stream of water passed while the metal was cooling. The iron for both castings was melted at the same time in two air furnaces, each containing 14,000 pounds of the same kind of iron. After melting, the liquid iron remained in the furnace one hour exposed to a high heat; and was then discharged by separate streams into a common reservoir. From the reservoir it issued in a single stream, which, after proceeding a few feet, separated into two branches, each leading to a separate mould. Both moulds were filled at the same time.

The solid casting remained in an open pit, and cooled in the usual manner.

The hollow casting was cooled, in the interior, by passing a stream

of water through the core, for a period of forty hours, when the core was withdrawn; after which, the water passed through the interior cavity formed by the core for twenty hours.

1169 *Report on the Manufacture and Proof of 8-inch and 10-inch Columbiads, Cast at Fort Pitt Iron Works by Messrs. Knap & Co.*, 1851.

Pages 184, 185.

Two 8-inch Columbiads were cast July 30th, 1851. The iron used was made at Greenwood furnace, New York, and was of the following qualities, viz: 36/100 of No. 1; 25/100 of No. 2; and 39/100 of No. 3; 28,000 pounds were melted in two furnaces (12,500 in one and 15,500 in the other), about three-fourths of which was of second fusion, and one-fourth of third fusion. The Columbiads therefore consist of about three parts of 3rd fusion and one part of 4th fusion.

After melting, the liquid iron remained in the furnaces two and a half hours exposed to a high heat, and was then discharged by separate streams into a common reservoir, at the same time. It was withdrawn from the reservoir in a single stream, which after proceeding a few feet separated into two branches, each leading to a separate mould, filling both molds at the same time.

Both of the moulds were placed in open pits; one of the castings was made solid, and cooled, in the usual manner, without heating or covering the pit; the other was cast hollow, by means of a core formed on a tube of cast iron, through which a stream of water constantly circulates while the iron is cooling. The core tube is water-tight and is closed at the lower end. The water is conducted to the bottom of the core through an interior tube placed in the center of the core, and open at its lower end. It ascends through the annular space between the two tubes, and is discharged from the core at a point above the casting, and flows off in a heated state.

A fire was kindled in the bottom of the pit, directly after casting, and was continued sixty hours. The pit was covered, and
1170 the iron case containing the gun mould was kept at as high a temperature as it would safely bear, being nearly to a red heat all the time.

The water passed through the core at the rate of 2½ feet per minute, or 150 feet per hour. At twenty-five hours after casting, the core was withdrawn; and the water thereafter circulated through the interior cavity formed by the ore at the same rate for forty hours; making 65 hours in all. The whole quantity of water passed through the casting is nearly 10,000 cubic feet, weighing about 300 tons, or about fifty times the weight of the casting. The heat imparted by the casting to the water, and carried off by the latter, is equal to 6 deg. on the whole quantity of water used.

Two 10-inch Columbiads were cast August 21st. Greenwood iron, of the same qualities as melted for the 8-inch gun, was used. About ⅓ consisted of 1st fusion; ⅔ of 2nd fusion; and ⅓ of 3rd fusion.

It was melted in three furnaces, containing 12,000, 15,000 and 19,000—in all 46,000 pounds. The liquid iron remained in fusion 2¼ hours, and was discharged from all the furnaces at the same time into a common reservoir, from which it issued in a single stream, and was conducted to the bottom of the gun pit, where it branched off, and entered the lower ends of both moulds at the same time.

Both moulds were placed in the same pit. One of the guns was cast solid; the other was cast on a hollow core, and cooled within, by a stream of water circulating through it, as before described.

1171 *Notes on the Construction of Ordnance, No.* 21.

WASHINGTON, *May* 14, 1863.

Fabrication of cannon in Russia.

An outline.

By Lieut. Michel Levitzky, Russian navy.

Translated from the "Revue Universelle des Mines," by Capt. C. S. Smith and Lieut. Rogers Birnie, Ordnance Department, U. S. A.

Historical Sketch.

Page 14.

In casting a piece of considerable volume, like a cannon, the operation is commenced by placing a number of crucibles in each furnace, calculating their number from the ingots of metal necessary to fill the mold; the operation should, of course, be so conducted that all the crucibles may come to the melting point at the same time. The cast-iron molds employed for casting small pieces have very nearly the same form as the finished pieces themselves. It is not the same, however, with cannon molds. The first form of a gun is nearly cylindrical, the interior walls of the mold being only slightly conical, from the summit to the base, in order to facilitate the withdrawing of the piece. The relation of the area of each section of the ingot to that of each section of the finished gun varies usually from 2 to 3. Previous to casting the mold is heated by filling it with red embers; the interior walls are rubbed with plumbago, or coated with whitewash or white clay, in order to render the surfaces smooth.

In castings of small dimensions the steel is turned directly into the mold from two crucibles, at first as rapidly as possible, afterwards slowly, but always continually. For large cannon, such as 12-inch guns, which weigh more than 85,800 lbs., the steel
1172 from the crucibles is run at first into a pool, from whence it afterwards flows in a continuous stream from the mold; after the mold is filled it is closed with a cast-iron cover loaded with weights, the pressure of which contributes to the production of a fine texture in the metal and a more compact grain. Sometimes, in

order to effect a more uniform cooling, the free surface of the metal is covered with powdered and sifted clay, which evidently acts to retard the cooling of the upper layers, which, if not checked, often proves injurious to the homogeneity of the metal. The operation of cooling the ingot for a large cannon requires ordinarily from 23 to 25 minutes.

The Pittsburgh Daily Commercial, Friday, Feb. 12, 1864.

One of the most important events in the history of the rebellion, and which inaugurates a new era in the manufacture of heavy guns, took place on Thursday between twelve and one o'clock at the Fort Pitt works. A gun with calibre of twenty inches diameter was cast on the Rodman principle, in some twenty-two minutes from the time of tapping the furnaces.

The arrangements for casting this mammoth piece of ordnance were most perfect, and during its process everything worked like clock-work. The amount of metal used for this huge gun was 85 tons, or 170,000 pounds. The metal was melted in three furnaces which were charged at five o'clock in the morning. At twenty minutes past twelve, everything being in readiness, the three furnaces were simultaneously tapped, and the molten metal was conveyed by means of three conductors to a large reservoir close to the mold. The mold was set perpendicularly in a mammoth pit, and was held in position by huge chains suspended from two large cranes of a lifting capacity of forty tons each, and worked by steam.

As soon as the reservoir was sufficiently charged, the metal
1173 flowed from it into the mold, and in twenty-two minutes from the time of tapping the furnaces the mold was filled to within a few inches of the top. As the mold settled, the mold was filled by the workmen with metal from furnaces held in reserve in case of accident. The casting was perfected without the slightest confusion, the whole being done under the immediate superintendence of Mr. Joseph Kaye, foreman of the works.

We are indebted to Captain Joseph M. Knap for the following statistics, which will give our readers a better idea of the magnitude of the casting:

Weight of gun in rough	160,000 pounds.
Weight when finished	112,000 "
Total length when finished	20 ft. 3 in.
Length of bore	17 " 6 "
Maximum diameter	5 " 2 "
Minimum "	2 " 10 "

The gun, it is estimated, will use a spherical shot of half a ton weight and a shell of seven hundred and fifty pounds. If the gun was rifled it would throw a solid shot of one ton weight. The amount of powder to be used in charging the gun is estimated from eighty to one hundred pounds. This gun is said to be the largest in the world, and to Pittsburgh belongs the honor of adding such a heavy piece of ordnance to the science of war.

The casting of the gun, as we before remarked, was on the hollow-core principle invented by Major Rodman, U. S. A. The core consists of an iron cylinder, half an inch in thickness, through which a stream of water is kept continually running during the process of casting. This cylinder is wrapped with rope, which is covered by sand, and outside of this for a short distance from the mouth of the mold is a sheet-iron cylinder. During the casting the water discharged from the core indicated a temperature of 40 to 42 degrees. The gun will remain in the pit undergoing the cooling processes some ten days or two weeks, after which it will be
1174 hauled out by means of the large cranes referred to, and removed in a railway truck to the finishing department of the works, where it will be placed in a lathe and finished.

It is not yet known what disposition will be made of the gun when completed, but it is thought not improbable that it will be placed in some of the defences of New York harbor. If so, we would not like to insure the safety of the "Black Prince," "Warrior," "Royal Oak" or "La Gloire," should they attempt an entrance of the harbor with warlike intent. One shot from the monster would crush such vessels to pieces.

Although the day fixed for the casting was necessarily kept quiet, a large number of ladies and distinguished military and scientific persons were present by invitation of Mr. Knap. Among those present we noticed the following gentlemen:

Major Dyer, of the Ordnance Department; Major Rodman, the inventor of the principle upon which the gun was cast; Capt. B. Aulick, ass't chief of Bureau of the Ordnance Department of the Navy; Capt. J. M. Berrian, inspector of ordnance U. S. Navy; Capt. Bennett, chief inspector of ordnance; Capt. Edie, chief of ordnance on Gen. Meade's staff; Capt. Hays, chief of ordnance on Gen. Pleasanton's staff; Prof. Baker, of the Western university, and others. Two distinguished representatives from abroad also witnessed the process of the casting, Marquis de Bascount, of the Italian army, and Capt. Goodenough, of the English navy. All these gentlemen were highly pleased with the great success of this experiment, and none more so than the last two named.

1175 No. II.) (Second series.

The Direct Use of Blast-furnace Metal in the Bessemer Process.

NOTE.—This report is printed, not as a publication, but simply for the convenience of my clients, and for their exclusive use.

A. L. HOLLEY.

New York, June, 1877.

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1177 *The Direct Process.*

Running iron from the blast furnace directly into the Bessemer converter has now been practiced long enough in Great Britain to test the commercial advantages of the system, to show its incom-

pleteness, and to suggest a remedy. It may in general terms be stated:

First. That with the slightly manganiferous iron ores best obtainable in Great Britain (which closely resemble those most used in America), the system realizes an economy, as nearly as it can be got at, of about a dollar a ton on rails.

Second. That this economy is less than that realized in France and Belgium with ores containing a considerable amount of manganese (see my Report No. 8, first series)—so much less as to somewhat disappoint the west-coast companies, which make their own iron close to their Bessemer works, and to quite reassure the Sheffield makers, who cannot work direct.

Third. The embarrassing feature of the direct process is the irregularity in the heat—that is to say, in the silicon of the charges—resulting in the large amount of scrap due to too little of this element, and in the increased number of second-quality rails due to too much of it; while in France, where 3 to 5 per cent. of manganese is the heating ingredient, there may always be an excess of this latter element without injuring the quality of the steel, although the variation of heat is here also, a serious difficulty. In other words, it has not yet been practicable to work the blast furnace with sufficient regularity to realize approximately the theoretical advantages of the direct process.

1178 Fourth. The obvious remedy is to mix a number of blast-furnace charges, so as to reduce the irregularity to a minimum. Two systems of doing this are on the eve of trial: the one is simply mixing so few charges in a tank that the metal will be drawn out before it chills; the other is to store a larger number of charges in a heated tank—that is to say, in an immense open-hearth furnace.

A few words of history may be of interest. Mr. Bessemer's early intention was to use blast-furnace metal direct. The earlier Bessemer practice, especially that in Sweden, was with metal right from the blast furnace. But this practice did not make headway, except where there was from 3 to 5 per cent. of manganese in the pig blown, for reasons just mentioned; so that while it soon became standard at Terrenoire and elsewhere in France, as well as in Sweden, and to some extent in Germany, yet in England it was not only unused but pronounced impracticable so late as September, 1874. During the Barrow meeting of the Iron and Steel Institute at this date, a discussion on the writer's paper on American rolling mills was allowed by Mr. Bell, then president, to drift into one of the most important and fruitful interchanges of opinion about not only the direct process, but about its advocates and its opponents, which ever occurred in England or elsewhere. So soon as the March meeting in 1875, Mr. J. T. Smith, of Barrow, who had previously intimated that the direct process could not be successfully carried out in England, frankly acknowledged that he had been laboring under an error, and he proceeded to tell what he had already accomplished in this direction at Barrow. Meanwhile, or shortly after, the West Cumberland, the Dowlais, and the Ebbw-Vale works had introduced the direct process; and they have all

been carrying it out with some degree of success, and also of improvement, ever since.

At an early period in the history of the Bessemer manufacture Mr. Bessemer proposed to run blast-furnace metal, on its way to the converter, directly into a large vessel partially filled with hot coke, the object being to not only maintain its heat but to
1179 increase its carbon. This arrangement was partially carried out in the Carnforth Bessemer plant, which was nearly completed early in 1874, but which has not yet been put into operation.

The West Cumberland Practice.

This is decidedly the best in Great Britain, because the arrangement of plant is most convenient, and the blast-furnace working, under the general management of Mr. Snelus, is most intelligent and quite uniform in its results.

There are two Bessemer pits, having two vessels each. The "A" pit has not been most conveniently adapted to the direct process. (The blast-furnace ladle and car are run upon a lift about 30 feet from the vessels, raised, and turned half round; then the ladle is tipped into a runner. There is a little more runner scrap than from cupola metal. As there are not blast furnaces enough to supply both pits, the cupolas of this "A" pit are run as before, and an occasional ladle of blast-furnace metal is got besides.)

The arrangement of the "B" pit is shown by Figs. II and III, and the blast-furnace ladle and car by Fig. I. The vessels face each other on the usual English plan, but they have been raised so that a platform could be placed between them, over the pit, high enough to clear the steel ladle, and low enough to allow the blast-furnace ladle to tip directly into either vessel. Thus the metal is poured into the vessel without any splashing and without any runner scrap or runner repairs. Blast-furnace metal is used in this pit almost exclusively. The spiegel is melted in cupolas.

The ladle carriage is built very strongly, of steel throughout. The ladle hangs between the wheels and low down; it is tipped either way by a worm. The whole apparatus, ready for use, weighs about ten tons. The ladle is lined with split brick and then with $\frac{1}{2}$ in. to 3 in. of loam. It will usually stand 16 to 18 charges before reloaming, but one cold charge may make a heavy scull. The ladles are thoroughly dried in an oven. There are 3 ladle cars and ladles.

The railway from the vessels to the furthest blast furnace is about 1,500 feet. It runs in a tunnel $10\frac{1}{2}$ ft. high, along the front
1180 of the line of furnaces, under the pig beds, and only 28 ft. from the centres of the furnaces, as shown by Fig. IV. The cost of this thoroughly good preparation for the direct process, was $25,000 gold. The metal flows into the ladle from the runner through a hole $2\frac{1}{2}$ ft. square in the tunnel roof. Thus the metal runs but about 15 ft.; the ladle is but slightly exposed to the weather when standing, and at the other end of the railway, the metal is poured directly into the vessel. These conditions are most

favorable for preserving the temperature of the iron. There is, however, no cover over the metal, except a little slag and fine coal. The ladle cars are drawn by a special locomotive, and are weighed on their way to the vessels.

A vessel charge is tapped into a ladle from two furnaces always, and sometimes from three. The greater part of the charge is taken from the furnace which is making the most suitable metal, or, if one furnace is working hot and another cold, the manager draws the best mixture he can, due regard being paid to the proper relief and working of the furnaces. But in order to draw a suitable mixture, the manager must know what sort of metal he can get from each furnace. His clue to this (for he can hardly get complete facts in the present state of the art) is threefold: 1st, he can tell that the metal is getting too little silicon by a black slag and by its running more sluggishly; 2d, he can in about half an hour get a rough analysis of silicon; and, 3d, he has reports of the blowing (hot or cold) of each vessel heat. All this is not in time, certainly, to enable him to immediately correct the working of the furnace, but it is in time to give him a pretty definite idea of what the furnace is likely to yield for several taps, and of the probable changes and of the suitable correctives. Silicon is, of course, regulated in a great degree by the amount of limestone charged with the ore. In the practice here, silicon can be reduced 1 per cent. in six hours, but to run it up 1 per cent. and work the furnace safely requires several days The slag is largely skimmed off from the stream of iron running into the ladle, and the tapping is done as rapidly as possible.

1181 The vessel charges are usually from 6½ to 8 tons, but they are sometimes below 6 tons. Ten heats per pit, per turn, is considered good practice; eleven heats are often obtained. It is but fair to say that more heats could be converted if the iron could be got, but not many more, on account of the cramped pit-room and handling facilities.

The average time of getting the metal from the furnace into the vessel, as witnessed during a number of operations by my assistant and myself, was about twelve and a half minutes, as follows: Filling the ladle from two furnaces, five minutes; running to vessel four minutes; pouring into vessel, three and a half minutes.

The irregularity of silicon, as before stated, is the only difficulty. As much as 2½ per cent. of silicon is required to enable the pit-scrap to be worked up in the vessel without making sculls. As little as 1.6 per cent. has been used, without putting scrap in the vessel, by means of very careful blowing, and Mr. Snelus says they could get on fairly with 1.8 to 2 per cent. The fact that the charges run at a higher temperature from the blast-furnace ladle than from the cupola, notwithstanding the transportation and exposure of the former, renders it practicable to work them with less silicon. The same result is promoted by the fact that from ¼ to ½ per cent. of silicon is oxidized in the cupola, and so is not available for heat-giving in the vessel. Mr. Snelus states that he has proved by some

hundreds of analyses that silicon is removed in the cupola when working gray—that is, average Bessemer—iron.

Upon a close observation of the blowing it occurred to me that this operation was carried on at a reduced air pressure when the rapid brightening of the vessel flame showed low silicon, the intention probably being to get up more heat by burning more of the silicon; also, that when the flame was for a long time sluggish and dull, showing high silicon, the blowing was done faster and at a higher pressure, which is supposed to burn less silicon; and also that the charges having high silicon were overblown, to thus remove this troublesome element. I subsequently ascertained
1182 that these theories were entertained by the manager of the Bessemer department, and that he thought he had proved them correct by the practice which I have just mentioned. When highly siliconized heats were overblown the spiegel charge (15 to 16 per cent. Mn.) was increased from 7 up to 9 per cent.

In a discussion of this general subject before the Iron and Steel Institute, at the Leeds meeting, in September, '76, Mr. Snelus (having possibly heard of Messrs. Hunt & Wendel's process of putting cold pig in the vessel to keep down silicon, then and since successfully practiced at Troy) said that if the silicon in the pig was much above 3 per cent. there was "danger of making silicon steel," and that "if they got pig with 3 per cent. of silicon in it he thought they might without any difficulty use up to 20 per cent. of cold iron in the converter." The fact that silicon is oxidized in the cupola makes it so much the more difficult to use a highly siliconized iron by the direct process. The trouble at West Cumberland, however, is lack of sufficient heat rather than too much of it.

The time of blowing direct metal is said to average three or four minutes longer than that of cupola metal. It can hardly be assumed that there are more carbon and silicon to be burned out of the latter, but the phenomenon, if it really occurs, can perhaps be indefinitely referred to the constant changing of affinities between oxygen and oxidizable metals at different temperatures. Direct metal has the higher temperature at the start, but we do not seem to be able to follow the reactions with much certainty.

The waste runs as low as 11 per cent., besides which there is, in good average practice, 3 per cent. of scrap. I found the waste on cupola metal from the same ores to be 14 per cent. in 1874, and I am informed that it has always been about that. Some of the American works are now running cupola metal with 11 per cent. waste and less. At Creusot and at Seraing the waste on cupola metal was 14 per cent.; on direct metal it is 10 to 11 per cent. Complete comparisons cannot, of course, be made without complete analyses. The yield stated by Mr. Snelus in September, 1876, in the discussion before the Iron and Steel Institute, was as follows: "B" pit, one fort-
1183 night—"total metal used, 1,033 tons; ingots made, 887 tons; ladle scull iron, 14 tons 12 cwt.; iron scrap cleanings of ladle, 1 ton 3 cwt.; steel scrap of all kinds, 14 tons 7 cwt.; yield of ingots, 85.8 per cent. on 14.2 waste; iron scull and scrap, say 1.5 per cent.; steel scrap of all kinds, 1.5 per cent., leaving absolute waste about

11 per cent." The yield of ingots in "B" pit, for the fortnight ending February 10, 1877, was a little above 86 per cent.; the yield in "A" pit, using chiefly cupola metal, the same fortnight, was under 82 per cent. The percentage of ingots in "B" pit, for the fortnight ending February 24, was above 86; that for "A" pit the same fortnight was a little above 83. But as irons from precisely the same ores were not used in both pits, the comparison is only a general one. The details and costs of ingots during these fortnights are given in tables at the end of this report.

In order to get a more uniform metal, Mr. Snelus is about trying the experiment of placing a 20-ton ladle on a hydraulic lift at the "A" pit, so arranged as to store, mix, and pour, say, three 6-ton to 7-ton blast-furnace taps, or to mix blast furnace and cupola metal. No doubt this body of metal will "live" if the ladle is thickly lined and well covered. Mr. Snelus has another object also; tapping half or a third of a vessel heat out of the blast furnace—in other words, tapping so often—wears out the tap-hole more rapidly; slag gets into the walls and weakens them. It is preferable in every way, as blast-furnace men well understand to tap a full hearth. At the same time improvements in working the furnace are gradually developing. More care is taken as to the selection of ores, the size of ore and limestone, the distribution of materials in the furnace, the temperature of the blast, and all elements of uniformity. Yet with all the care taken at Terrenoire and at Creusot, with manganese as an heating element, there is more or less trouble from the variation in the temperature of the charges. Ores will never be uniform; hence uniform results in the Bessemer department can hardly be expected, unless a number of blast-furnace charges are mixed. This would seem to be the theoretical solution of the problem.

The conditions which Mr. Snelus proposed to himself, 1184 when he set out to use direct metal, he thus stated at the Iron and Steel Institute discussion before mentioned: "1st. To construct a ladle and carriage that could be moved about with safety and celerity without being of an undue weight; that the ladle should be placed in the most secure position upon its carriage; that it should be easily tipped for pouring out the metal; lifted out with facility when it required to be changed; and that the man in charge of the ladle should be in a good position for turning it over, so that he could not only see well what he was doing, but be out of danger from any splashes of metal. 2d. That all turn-tables and lifts should be avoided. 3d. That in order to produce the utmost economy the ladle should be brought as near as possible to the blast furnaces, so as not to cool the metal or have more scrap than necessary, and that the metal should be poured directly from the ladle into the converters, in order to avoid the cost and waste of runner-making."

English experts have agreed very generally with Mr. Snelus in this matter. As to the avoidance of lifts, it is hardly fair to refer to the fact that he is about to use one with his 20-ton mixing ladle, for his plant is so arranged that he cannot well avoid it. The lift

practice at Creusot, Terrenoire, and Seraing, however, perfectly satisfactory, and a lifting apparatus, most highly elaborated to save time in transferring the metal, may often cost but a fraction of the expense of a long elevated railway.

The results at West Cumberland may be summed up as follows: The saving lies in avoiding the cost of remelting and in reducing the waste of iron which would occur in the cupola, and also the waste which is due to higher siliconization of the irons which the indirect process would require. There is also some little avoidance of sulphur which cupola coke would impart, although Mr. Snelus says, from his many analyses, that gray iron does not take up sulphur in the cupola. These savings amount to $1.25 gold per ton on rails, but would be considerably more were it not for excess of scrap due to the silicon running too low, and of second-quality steel due to its running too high. It is difficult to tell exactly what the saving is chiefly on account of the impossibility of finding out just how much of what comes from the blast furnace is metal. Mr. Snelus allows 6 per cent. for sand and slag.

1185

Although the results are constantly improving, it is admitted at West Cumberland that the cupola practice is still the best for special steels where great regularity is required.

The Barrow Practice.

As this practice presents certain features of difficulty to a greater extent than any other in England, it was examined in some detail. These difficulties are, 1st, great variation in the silicon, partly due to variation in the ores and partly to imperfect blast-furnace working; 2d, long transportation of the melted metal from the furnaces to the vessels—nearly two miles.

By referring to the map of the Barrow plant in my report No. 7, first series, it will be observed that fourteen blast furnaces stand in one line and the Bessemer works and rolling mills in another line, the two being separated by the Furness railway, over which there is a large passenger and freight traffic. It would be unsafe and inconvenient to allow the melted-metal trains to cross this railway and its numerous sidings by angle frogs, but it was found practicable to switch it across at a point some three-fourths of a mile higher up where there were fewer sidings, and even then metal trains are often delayed by the regular traffic. One track on each side of the Furness railway is kept entirely clear for the metal train, which consists of two ladle cars and a special locomotive. The metal track runs in an open cutting with vertical walls along the foot of the pig beds of the fourteen blast furnaces, about sixty feet from their tap holes, and the melted iron flows to the ladle through ordinary sand runners. Thence the ladle cars run over the line described and up inclines to a point about thirty feet distant from the vessels, and the metal has to flow this additional distance through sand runners also. The only pits as yet supplied with direct metal are (see map

referred to) the two three-vessel pits and the right-hand one of the two pits next the Walney road.

1186 In the early ladle car the ladle hangs on trunnions outside the front axle, at the extreme end of the frame, the other end being counterweighted. The ladle slides forward as it is tipped by a worm, in order to concentrate the stream of iron. In the *the* new ladle car the ladle is hung just behind the front axle, thus doing away with the counterweight. Both cars are "one-enders" and the ladle tips in a plane parallel to the rails, while the West Cumberland car is a "double-ender" and the ladle tips either way at right angles to the rails. If the iron were poured from a height of four to five feet directly into the runner, it would splash out, causing much scrap; it is therefore poured into a funnel-shaped receiver of about four feet internal diameter, whence it flows by a hole in the side to the runner. We may note in passing, that while pouring directly into the vessel, as at New Cumberland, is the best possible plan, a ladle mounted on a hydraulic lift and raised gradually, so as to preserve a low and uniform fall of the metal (as at the Bethlehem works,) would save much scrap and also some cost of construction as compared with the Barrow elevated railway. Tapping the ladle at such a point as might be most convenient, would probably have been an improvement, as to both fall of metal and construction, over the end-tipping.

The ladle is lined with split brick, a small angle iron being riveted around the top to keep the brick in. Then there is a loam lining 1½ in. thick at the top and 3 in. at the bottom, and there are a few vent-holes in the bottom. A ladle lasts 12 to 15 charges before getting too full of scull and slag; then the loam is renewed and thoroughly dried in an oven. There is no cover over the metal except an inch of fine anthracite, and yet with this thin lagging the metal has not seriously chilled when the ladle car has been off the track for three hours.

An entire blast-furnace hearthful is tapped at once; half runs into one ladle and half into the other—about seven tons into each; the two ladles are then run up and backed down upon the two platforms (formerly cupola floors) behind the vessels, at about the

1187 same time, and both heats are blowing at once. Only two pits were running while I was last at Barrow, and these used direct metal exclusively; in fact, the cupolas had to be removed in order to get the direct-metal railway in. There is no mixing of the metal: the vessels must take what comes from one furnace, but, as the metal supply is in excess of the demand, the furnaces that are running best may be tapped into the ladles. This matter is in charge of a man, who goes back and forth on the ladle train, and is thus constantly aware of how the metal is blowing. Four men, at 5s. per day each, are employed in transferring the metal from the furnace to the vessel; there is also a weigher, who keeps these and other weights.

The time occupied from the tapping of the blast furnace to the turning up of the vessel, on three consecutive trips we made on the

ladle train, were 17 minutes, 22 minutes, and 20 minutes, respectively.

The yield is stated to be 450 to 500 tons of ingots per 24 hours in two 3-vessel pits and one 2-vessel pit. Two pits were running at about this rate when I was at the works. The three pits take the product of ten blast furnaces. The heats number as much as 12 tons per 3-vessel pits per turn, but their weights are very irregular; they sometimes run as low as 4 tons, and are often 8 tons. They are always small and cold on Mondays.

While the Barrow ores have much more silica than those used at West Cumberland, and hence make a hotter blowing iron, there is considerable trouble from cold charges, and quite as much from waste and cold-shortness caused by too much silicon. The Barrow Bessemer manufacture has never been so regularly conducted as that at some other places, and, although it is greatly improved since I saw it in 1874, it is still pretty often in trouble on one side or the other of the silicon line. With Barrow ores alone, the silicon in the pig averages 3½ per cent., and may be kept pretty regular; but a varying quantity of varying Irish ores is also used, and these are said to cause the irregularity. Whatever the cause, the silicon is constantly varying as much as one per cent.—that is, from about 2 to 3 per cent.

1188 The chief trouble caused by too little silicon is, of course, sculling and scrap. Besides the ordinary scrap, about once a week a whole charge gets so cold in the steel ladle that it can only be got out by dumping it into the pit; this scrap is worked over in the blast furnace. But another trouble from too little silicon seems to be notably developed at Barrow—slopping out of the vessels is excessive, and this is mostly loss.

The waste due to an excess of silicon is well known. The cold-shortness due to the same cause, the Barrow managers do not try to remedy by slight overblowing, as at West Cumberland.

When silicon runs regularly pretty high, a double economy is realized—keeping down waste and using up scrap—by putting 10 to 15 per cent. of rail ends, etc., into the vessel and some into the ladle. The theory, however, obtains among the foremen, that this already decarburized metal wastes more than pig iron in the vessel!

The loss, however, notwithstanding all drawbacks, has been materially reduced. It used to be some 17 or 18 per cent.; now it is about 15 per cent., of which 3 per cent. is iron and steel scrap, leaving 12 per cent. actual waste of metal. Mr. J. T. Smith stated at the Iron and Steel Institute meeting before referred to that the iron ladle scrap is now but 1¼ per cent. He further stated that the loss in the converter had formerly been as high as 30 per cent. with some mixtures of the Barrow ores.

Carbon tests by color are made of each heat, and this practice, never employed here until direct metal was used, is considered a great refinement—so it is, for Barrow. The sulphur in the pig is often determined, but there are no short analyses of silicon as there are at West Cumberland.

The saving by the direct process at Barrow is not claimed to be

75 cents per ton on rails, but there is also the indirect advantage of an improved and more uniform blast-furnace practice, so that the pig iron made for sale is of a more satisfactory character. Mr. J. T. Smith has publicly stated that the quality of the Barrow steel had, on the whole, improved since the direct process had
1189 been in use, and he attributes this chiefly to the better blast-furnace practice which has been forced upon them.

The Dowlais Practice.

Of this little need be said, as it is not remarkable in any way, and does not offer so good a field for profitable study as that at West Cumberland or that at Barrow.

The furnace plant is on a higher level than the Bessemer works, and the two are a little further apart than those at West Cumberland. The ladle car comes down a rather complex railway having a grade of 1 in 55. The car is run up the cinder-fall to a point very near the furnace tap-hole. The ladle is tapped into the converter instead of being tipped; hence the ladle and car are simple and cheap. Tapping seems quite satisfactory in every respect. About a thousand tons a week are taken to four vessels, and much more will soon be taken from other furnaces. Mr. Menelaus stated before the Iron and Steel Institute that the direct plan is effecting about the same saving as elsewhere, and that it does not affect the quality of the steel; "he did not assert that the steel was better, but certainly it was no worse." Mr. Menelaus also intimated that the direct Bessemer manufacture might have to be carried on Sundays also, in order to work up the Sunday product of the blast furnace and to keep the product more uniform.

The Ebbw-Vale Practice.

This, like the Dowlais practice, need not be discussed in detail, for the same reasons. The Bessemer plant is about three-quarters of a mile from the furnaces, and the connecting railway has sharp curves and steep grades, in some places 1 in 40. The crust of slag on the ladle prevents the metal from slopping over while running at ten miles an hour upon this road. The metal has been kept in the ladle over an hour, in some cases, without seriously chilling. Metal for some forty Bessemer heats per day is taken direct. The waste was about 16 per cent. when the iron was remelted; now it is from 13 to 14 per cent. This is due to working with a little
1190 less silicon—1¾ per cent. has been found to answer—and to the saving of oxidation in the cupola.

Unfinished Works.

The most unique Bessemer works I have ever seen is nearly completed at Moss Bay, a suburb of Workington. The vessels stand side by side and high, so that there is no pit. In front of them there is, not a ladle crane, but a high-jib hydraulic crane. This crane, by »o

means of a yoke, lifts the ladle of iron to the vessel nose, and it also, by means of a yoke, holds the steel ladle under the vessel nose while pouring, and then transfers it to the ladle crane, which stands at one side. On the other side, standing upon the general floor, there is to be a 60-ton reverberatory, coal-fired furnace, or else there will be two 40-ton furnaces—this point had not been settled when I was there, although the rest of the plant was nearly done.

The blast furnaces are about 1,000 feet away, and the direct-metal railway runs into the converting works at one side of the vessels on the general level. From this point the direct-metal ladle may be lifted to the vessel by the high-jib crane as before described, and tipped into the vessel. Or, by means of another lift or crane (not yet constructed), the ladle may be lifted to such a height that its contents may be tapped out into the large reverberatory furnace. In this furnace it is the intention to store and keep hot some 60 tons of iron from all the blast furnaces. The vessel charges will be tapped out as required into a ladle, raised by the high-jib crane, and poured into the vessel.

Although this large furnace may be the best means of mixing metal so as to get a uniform result, the complex manipulations due to the arrangement described seem likely to take an unnecessary amount of time and labor. The metal is lifted four times before it is run into the ingot moulds—once to the big furnace, once to the vessel, once to the ladle crane, and once by the ladle crane. And it is going to be a somewhat difficult matter to stop the tap-hole of a furnace with 50 tons of fluid behind it. Of course the ferro-static pressure may be made small by keeping the bath shallow,
1191 and the great surface thus exposed would be favorable to heating the metal. I am promised an early account of the results of this experiment.

It is but fair to Mr. Z. S. Durfee to state that he has long advocated the use of a large Siemens furnace to melt and mix metals for the converter, principally for the purpose of using irons low in silicon, so as to save waste; he would substitute the heat imparted in the gas furnace at the expense of coal for that generated by the combustion of silicon at the expense of iron.

Messrs. Bolckow, Vaughan & Co. have nearly completed a Bessemer plant at Eston, near Middlesborough, under the superintendence of Mr. E. W. Richards, late manager at Ebbw-Vale. The general features of the plant were copied from my designs; the vessels are high and sit side by side so as to leave room for three ingot cranes; and all the heretofore deep pit-work is done in an ample space on the general level. There are two plants having two vessels each, also six blast furnaces in a line. The tap-holes of the latter stand 10½ feet above the railway on the general level, so that the metal readily flows into the ladle. At the converting-house, a few hundred feet away, the ladle carriage is lifted between the converters by a hydraulic hoist; thence it is run upon a traverse table on the platform in front of the converters, so that the ladle may be tipped directly into either of them. This arrangement is illustrated by engravings in Engineering, November 10, 1876.

French and Belgian Practice.

This was described in detail in my report No. 8, first series. It has not since that time been materially changed.

At Creusot such ores are employed as will give 3 to 6 per cent. of manganese in the pig; when manganese is high, silicon is kept low. The attempt is to keep the manganese up to four per cent. and the silicon down to 2 as regularly as possible. The highest per cent. of silicon allowable is 3, the least is 1.8. There is rarely over 5 per cent. of manganese in the pig, and the least allowable is 3
1192 per cent. The blast furnaces are 350 to 500 feet from the converters; the ladle carriage is run to a point near the furnace tap-holes, transported on the general level, raised by a hydraulic lift at the rear of what was formerly the melting-house, and run to a point some 20 feet from the vessel noses, where the ladle is tipped and the metal received, not without much spattering in a spout. The blows often last as long as thirty minutes.

Sometimes the metal is underblown, so as to leave in the proper amount of carbon and manganese. This point is determined by turning the vessel down at the proper indication of the spectroscope, and then taking out some slag and examining the color of its fracture; also by hammering the little globules of steel that lodge in the slag, and noticing their malleability when cold. More blowing may be done, or spiegel or fluid pig may be added as required. No spiegel is added when the tests show the metal to be right, as they usually do. The slag is colored chiefly by manganese, but indicates also the variations in carbon. A lemon-colored slag indicates high manganese and 0.75 carbon or more. The yellow grows dark and then brown, and finally blue-black as blowing continues; the latter color means carbon, about 0.15. But the slag test alone is not very trustworthy, except when the silicon is uniform—for this also changes its color. Usually the metal is blown quite down, and spiegel is added as in our own works. For most uses the steel contains from $\frac{3}{4}$ to 1 per cent. of manganese. The Creusot managers are very fond of this ingredient, chiefly because it makes the metal lie quietly and set soundly in the moulds, and because it imparts a high degree of malleability to the product at all working heats.

There are eleven blast furnaces, the latest and best of which are $65\frac{1}{2}$ by $19\frac{1}{2}$ feet, for 60 per cent. ores. There are three pairs "10-ton" Bessemer vessels, but only two are running at present. One vessel in each pit is always standing still for repairs. The largest product of the two pits is 200 tons per 24 hours, or about 15 heats of about 7 tons each per pit. The waste runs from 10 to 11 per cent., not including scrap.

The blast-furnace practice at Creusot is carried on in a thor-
oughly scientific manner, and the ores used are pretty uni-
1193 form; and, moreover, too much of the heating-element manganese will not harm the steel, as too much of the heating-element silicon would, so that the silicon may always be kept

low; heating power is not solely dependent upon it, and manganese may run as high as it will, without making any serious trouble. And yet with this great advantage the Creusot managers confess that it is very difficult to keep the product uniform by the direct process. But they can use no other, as there are no remelting furnaces except for spiegel.

The use of manganese in the charge while blowing rather than its exclusive application after the charge is blown is no doubt a good thing. The manganese must cleanse the bath more thoroughly from oxide of iron and from sulphur, when it is constantly boiling together with the whole mass of metal, than when it is only mixed by pouring into the vessel and into the ladle. In the manufacture of steel castings at Terrenoire, in the open-hearth furnace, a small bath of spiegel to start with keeps the metal from oxidizing, and the same result probably occurs, to a great extent, from the use of manganese in the Bessemer charge.

At Terrenoire the converting-house and blast-furnace casting-house are under the same roof, so that there is the shortest possible transportation of metal. Two furnaces are tapped into the ladle to make a Bessemer charge. The ladle car is hoisted to the level of the vessel, run forward, and tipped into a short spout leading to the vessel. This character of the pig is very like that used at Creusot—in fact, it is made from substantially the same ores. The 3 blast-furnace stacks are about 50 x 13 ft., and have Cowper stoves; each stack makes from 42 to 48 tons per twenty-four hours. The ore is not hand-picked for Bessemer pig (although it is for ferro-manganese), but samples from each car-load are analyzed. The results of the direct process are so satisfactory that some $5 per ton are saved as compared with the old, indirect process; this, however, may not all be due to the direct process, but partly to more economical working in all details.

1194 At St. Chamond, near Terrenoire, the conditions and results are much the same. The blast furnace is 300 ft. away from the vessels, and the direct-metal ladle is raised by a hydraulic hoist near the vessels.

At Seraing, in Belgium, the plant is new and the practice is very good. The two blast furnaces running are 60 ft. high by 16.4 ft. in the boshes. The ores average 46 per cent. of iron, 14 to 15 per cent. of silica, 4 of alumina, 3 of lime, and 3 of manganese. Each furnace yields about 72 tons of pig per day.

The 4 vessels (2 of which run on direct metal) are within 200 ft. of the furnaces, and the transfer of metal is by means of a ladle car and lift, as at Creusot. The greater part of the charges are blown "young," by means of the slag and metal-globule test just described, and no spiegel is added. The quality of the product is pronounced decidedly better than that of remelted irons from the same ores. The silicon in the iron is kept down to 1.70 to 2 per cent., and the manganese up to 3 per cent. or a little more, as nearly as possible. The waste in blowing is from 10 to 11 per cent., which is a saving of nearly 3 per cent. over remelting. The vessel charges average a little above 14,000 lbs., and two vessels take the product of two fur-

naces. The ingot yield of 2 vessels is thus something over 125 tons per 24 hours. The direct process, with the kinds of ore used, is considered a great success, and there is apparently less difficulty here than elsewhere from cold charges.

Conclusions.

As before stated, it has not been the object of this paper to go into details of practice which cannot, from the nature of our accessible ores, be readily copied in our own works; but it has been attempted to give all useful facts regarding the most suggestive English practice, with ores and conditions similar to our own. It should appear, I think, from the facts stated—

First. That we are not, in the present state of the art, incurring an important loss by selecting and remelting pigs. This remark will probably apply even to those works which include a 1195 considerable and convenient blast-furnace plant. If with a less experimental ore supply than we have, and with a better average blast-furnace practice than our own (although it may not be better than our best), and with so great a number of furnaces that one or another may be relied on for approximately suitable pig—if with all these advantages the English works are in such serious trouble about silicon that they are devising expensive remedies in the way of mixing furnace products, then it seems reasonable to suppose that we, with our more experimental ores and less refined practice and fewer furnaces, should encounter still more serious embarrassments; and the existing margin of profits, even at West Cumberland, is not large enough to carry more than its present burden.

Second. We should for some time confine our efforts to the preliminary department of the direct process—to increasing our uniformity of blast-furnace working and product. The Barrow managers seem to attach as much importance to the increased value of the pig they sell as to the cheaper product of that which they use; we may, therefore, find a profit in getting ready to adopt the direct process, as well as in adopting it.

Third. Unless a pair of vessels—a complete plant—can be wholly supplied with direct metal, there will be little economy in using any; for it will take nearly as much labor and more coal per ton of ingots, to remelt part of the iron as compared with remelting it all.

Fourth. But if the storage of a large quantity of iron in a reverberatory furnace or other reservoir should prove successful, then a few blast furnaces making even an irregular product, and, if necessary, working in connection with cupolas, would largely economize the Bessemer manufacture.

In fact, this mixing of irregular irons on a very large scale, thus avoiding the expensive niceties of ore selection and the necessity of many furnaces, is the theoretical key to the situation. When the way to its successful adoption is demonstrated, the direct process will undoubtedly have great advantages, even over the present

practice on the continent, which employs manganiferous ores. But until this large-scale mixing is developed, it should not
1196 appear that the use of our comparatively irregular blast-furnace metal, and more especially the use of part blast-furnace and part cupola metal, can result in any substantial saving.

But the mixing problem is not such a difficult one. A small amount of flame, spread over a large surface of metal, should certainly keep it hot for a long time, seeing that the metal will keep hot in a ladle exposed to the air for an hour or more. And should there be any trouble about stopping the tap-hole in a large storing furnace, it would not be a very difficult or expensive matter (considering the Pernot revolving-hearth experience) to tip the whole hearth enough to pour a charge.

So that, while we congratulate ourselves that the direct-metal users have no large advantages over us in the present state of the art, we may look forward to the development of the metal-storing problem with good hope, not only of more economical manufacture, but of more uniform product.

There are appended seven tables of costs of ingots and rails. The West Cumberland ingot costs show a small saving due to the direct process, but the saving before mentioned ($1.25 per ton) is got from a year's work rather than from that of several fortnights. These cost sheets are appended chiefly to show actual results in England rather than to show comparisons between the direct and indirect processes. They have been reduced to United States terms for the convenience of my clients; I have the originals on the official forms, as copied, under my inspection, from the books and certified to by the managers.

(Here follow tables marked pp. 1196*a* to 1202, inclusive.)

1205 "*Engineering.*"

Vol. 30, page 95, July 30, 1880.

Barrow Hematite Iron & Steel Works.

"When the Iron and Steel Institute held their meeting at Barrow, in 1874, we gave a lengthened account of these works (see Engineering, vol. XVIII, page 228). During the past six years, although the general plan remains the same, a large number of improvements have been made, and we therefore propose to supplement our previous article, so that our readers may have a more correct impression of the works, as they will be seen next week during the visit of the members of the Institution of Mechanical Engineers. * * *

At the iron works two considerable alterations have been made. The long row of fourteen blast furnaces had been reduced to twelve, and changes have been necessitated by the introduction of the "direct process," which involves the transportation of the iron molten from the blast furnace direct to the Bessemer converter. * * *

To carry out the direct process a siding has been constructed at

TABLE I.

Cost of Ingots.—Indirect Process.

Cost of Making 854 *tons* 389 *lbs. of Bessemer Ingots.*

West Cumberland Iron and Steel Co.

"*A*" *Pit.* *Fortnight ending Feb.* 10, 1877.

Ratio per ton. Tons.	Ratio per ton. Lbs.	Description.	Weight. Tons.	Weight. Lbs.	Rate. Dols.	Rate. Cts.	Totals. Dols.	Totals. Cts.	Grand totals. Dols.	Grand totals. Cts.	Cost per ton. Dols.	Cost per ton. Cts.
		Pig-iron:										
		W. Cumberland, No. 2	237		16	25	3851	25				
		" No. 3	189		15	625	2953	13				
		Lawther, No. 2	92		16	375	1508	50				
		" No. 3	127		16	375	2079	62				
		Moss Bay, No. 2	43		16	44	706	81				
		Derwent, No. 1	93	1120	16	44	1536	90				
		" No. 3	139		16	44	2109	75				
		Steel scrap	34	1120	13	75	474	37				
		Broken moulds and bottoms	16		16	25	260	00				
1	989		964				15588	33				
		Credit:										
		Scrap made, 33 t. 1120 lbs. @$13 75—$460 62										
		Ingot'ends, 5 t. 742 lbs. @$21 18—$112 95										
	116	Castings, 5 t. 700 lbs. @$50 —$265 63	44	322			839	20				
1	173		919	2018					14699	13	17	211
		Spiegel:										
		Dowlais	16		29	375	470	00				
		Darwen	3	1120	30	625	107	19				
		Ebbw-Vale	50	1652	29	375	1666	60				
		Ferro-Manganese, A		84	72	08	2	70				
		" E		645	119	68	34	41				
	201		76	1261					2280	90	2	670
	470	Coke	179	336	5	00			895	75	1	048
	100	Lime	38	1120		875			33	66		039
		Ingot moulds and bottoms:										
		45 t. 1764 lbs. @$23 48—$1079 94										
		Cr. for sc'p, 45 t. 1764 lbs. @ 16 25— 744 94							335	90		393
	354	Boiler coal	211	896	2	25	475	64				
	52	Vessel coal	20		2	25	45	00				
			231	896					520	64		609
		Castings							170	35		199
		Bar-iron							59	38		069
		Bricks and blocks							23	25		027
	99	Fire-clay and loam sand	38	560	2	625			100	38		117
	220	Gannister	83		5	708			473	79		554
		Tuyeres, nozzles, seats, etc.							293	10		343
		Stores							216	44		253
		Wages: Making ingots							1265	38	1	481
		" Repairs							350	47		410
		Rent, rates, taxes, stationery, travelling expenses, interest, etc.							400	00		467
		General repairs							106	75		125
		Debentures, depreciation, etc.							425	00		497
		Cost of ingots							22650	27	26	52

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TABLE II.

Cost of Ingots.—Indirect Process.

Cost of Making 966 tons 512 lbs. of Bessemer Ingots.

West Cumberland Iron and Steel Co.

"A" Pit. *Fortnight ending Feb. 24, 1877.*

Ratio per ton Tons.	Ratio per ton Lbs.	Description.	Weight. Tons.	Weight. Lbs.	Rate. Dols.	Rate. Cts.	Totals. Dols.	Totals. Cts.	Grand totals. Dols.	Grand totals. Cts.	Cost per Ton. Dols.	Cost per Ton. Cts.
		Pig-iron:										
		W. Cumberland, No. 2	378	1120	16	25	6150	62				
		" No. 3	401		15	625	6265	63				
		Lawther, No. 1	19		16	375	311	12				
		Moss Bay, No. 2	21		16	43	345	29				
		Derwent, No. 1	99		16	75	3559	38				
		" No. 3	213	1120	16	75						
1	269	Converter scrap	37	1120	13	75	515	62				
		Broken moulds and bottoms	12	1120	15	625	195	32				
			1082				17342	88				
		Credit:										
		Scrap made, 98 t. 1120 lbs. @ $13 75 = $391 87										
		Castings, 5 t. 8 lbs. @ $50 00 = 250 00										
	90	Ingot-ends, 5 t. 826 lbs. @ $20 10 = 108 25	38	1954			750	25				
1	179		1043	286					16592	63	17	176
		Spiegel:										
		Dowlais	11	114	29	375	1117	35				
		Ebbw-Vale	96	2156	29	375						
		Darwen	14	112	30	625	430	29				
		Bolckow's	16	560	26	25	436	75				
		Ferro-Manganese, A	2	1232	72	08	183	80				
	164		79	1907					2168	29	2	243
	427	Coke	184	1120	5	00			922	50		954
	80	Lime	34	1120		825			30	18		031
		Ingot moulds and bottoms:										
		41 t. 412 lbs. @ $24 44 = $1012 02										
		Cr. for scp., 41 t. 412 lbs. @ $15 625 = 646 95	....	....	....	....	....	....	365	07		377
		Boiler-coal	198	1344	2	25	446	85				
		Vessel-coal	18		2	25	40	50				
	502		216	1344					487	35		507
		Castings	....	....	....	....	....	....	139	54		142
		Bar-iron	....	....	....	....	....	....	36	17		037
		Bricks	....	....	....	....	....	....	27	63		029
	95	Fire-clay and loam-sand	41	560	2	625			108	29		111
	154	Gannister	66	1120	5	708			379	60		392
		Tuyeres, nozzles, seats, etc.	....	....	....	....	....	....	283	27		293
		Stores	....	....	....	....	....	....	147	77		152
		Wages: Making ingots	....	....	....	....	....	....	1444	75	1	496
		" Repairs	....	....	....	....	....	....	341	73		353
		Rent, rates and taxes, stationery, travelling expenses, interest, etc.	....	....	....	....	....	....	400	00		413
		General repairs	....	....	....	....	....	....	120	75		125
		Debentures, depreciation, etc.	....	....	....	....	....	....	425	00		439
		Cost of ingots	....	....	....	....	....	....	24420	42	25	280

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TABLE III.

Cost of Ingots.—Direct Process.

Cost of Making 914 tons 714 lbs. of Bessemer Ingots.

West Cumberland Iron and Steel Co.

"B" Pit. *Fortnight ending Feb. 10, 1877.*

Ratio per ton. Tons.	Ratio per ton. Lbs.	Description.	Weight. Tons.	Weight. Lbs.	Rate. Dols.	Rate. Cts.	Totals. Dols.	Totals. Cts.	Grand totals. Dols.	Grand totals. Cts.	Cost per ton. Dols.	Cost per ton. Cts.
		Pig-iron:										
		W. Cumberland, No. 2	763	560	16	25	12402	80				
		" No. 3	80		15	625	1250	00				
		Lawther, No. 2	12	1120	16	375	204	69				
		" No 3	24		16	375	393	00				
		Derwent, No. 1	28		16	437	460	25				
		" No. 3	47		16	437	772	55				
		Steel Scrap	19	1120	13	75	268	12				
1	148		979	560			15751	41				
		Credit:										
		Sc'p made, 30 t. 1120 lbs. @ $13 75 —$429 375										
	82	Ingot-ends, 3 t. 406 lbs. @ $20 375— 465 625	33	1526			485	00				
1	66		940	1274					15266	41	16	70
		Spiegel:										
		Dowlais	19		29	375	558	13				
		Ebbw Vale	62	728	29	375	1830	78				
		Darwen	5	1904	30	625	179	17				
		Ferro-Manganese, E		280	119	58	14	95				
	214		87	672					2583	03	2	825
	203	Coke	82	1680	5	00			413	75		452
	27	Lime	10	2016		875			9	54		010
		Ingot moulds and bottoms:										
		36t 1879 lbs @ $23 50—$869 87										
		Cr. for scrap, 36t. 1879 lbs. @ $16 25—$598 60	....	....	....	....	....	....	271	27		306
	458	Boiler-coal	211	896	2	25	475	65				
	54	Vessel-coal	22				49	50				
			233	896					525	15		574
		Castings	....	....	....	....	....	....	170	35		186
		Bar-iron	....	....	....	....	....	....	59	38		065
		Bricks	....	....	....	....	....	....	22	87		025
	55	Fire-clay and loam-sand	22	560	2	625			58	50		063
	163	Gannister	66	1120	5	708			380	10		415
		Tuyeres, nozzles, seats, etc.	....	....	....	....	....	....	235	46		257
		Stores	....	....	....	....	....	....	216	44		236
		Wages: Making ingots	....	....	....	....	....	....	1294	60	1	416
		" Repairs	....	....	....	....	....	....	350	50		383
		Rent, taxes, rates, stationery, travelling expenses, interest, etc	....	....	....	....	....	....	400	00		437
		General repairs	....	....	....	....	....	....	114	25		125
		Debentures, depreciation, etc	....	....	....	....	....	....	425	00		465
		Cost of ingots	....	....	....	....	....	....	22796	60	24	94

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TABLE IV.

Cost of Ingots.—Direct Process,

Cost of Making 956 tons 284 lbs. of Bessemer Ingots.

West Cumberland Iron and Steel Co.

"B" Pit. *Fortnight ending Feb. 24, 1877.*

Ratio per ton. Tons.	Ratio per ton. Lbs.	Description.	Weight. Tons.	Weight. Lbs.	Rate. Dols.	Rate. Cts.	Totals. Dols.	Totals. Cts.	Grand totals. Dols.	Grand totals. Cts.	Cost per ton. Dols.	Cost per ton. Cts.
		Pig-iron:										
		W. Cumberland, No. 2	868	1792	16	25	14128	00				
		" No. 3	68	15	15	625	1062	50				
		Isawther. No. 1	49	1120	16	375	810	37				
		Derwent, No. 1	22		16	43	361	62				
		" No. 3	25	1120	16	75	427	13				
		Broken moulds and bottoms	9		15	625	140	62				
1	803		1042	1792			16920	44				
		Credit:										
		Scrap made, 25 t. 1120 lbs. @ $13 75—$350 63										
	70	Ingot-ends, 4 t. 1281 lbs. @ $19 75— 90 18	30	161			440	81				
1	133		1012	1631					16479	63	17	237
		Spiegel:										
		Dowlais	13	252	29	375	385	16				
		Ebbw-Vale	25	980	29	375	747	21				
		Bolckow's	14	84	26	875	377	25				
		Darwen	8		30	625	245	00				
		Ferro-Manganese, A	2	1382	72	08	188	63				
	148		63	458					1943	25	2	032
	264	Coke	70	1120	5	00			352	50		368
	44	Lime	18			803			16	19		016
		Ingot-moulds and bottoms:										
		37 t. 548 lbs. @ $24 33 —$902 87										
		Cr. for scrap, 37 t. 548 lbs. @ $15 605—$581 95							320	92		335
		Boiler-coal	198	1344	2	25	446	85				
		Vessel-coal	20		2	25	45	00				
	512		218	1344					491	85		514
		Castings							139	55		514
		Bar iron							36	16		037
		Bricks							2	18		014
	49	Fire-clay and loam-sand	18		2	603			47	75		049
	114	Gannister	48	1120	5	708			276	85		289
		Tuyeres, nozzles, seats, etc							235	01		245
		Stores							147	78		154
		Wages: Making ingots							1377	41	1	440
		" Repairs							341	73		357
		Rent, taxes and rates, stationery, travelling expenses, interest, etc							400	00		418
		General repairs							119	50		125
		Debentures, Depreciation, etc							425	00		444
		Cost of ingots							23164	76	24	22

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TABLE V.

Cost of Making 1709 tons 1854 lbs. of Bessemer Steel Rails.
West Cumberland Iron and Steel Co.
Fortnight ending Feb. 10, 1877.

Ratio per ton. Tons.	Ratio per ton. Lbs.	Description.	Weight. Tons.	Weight. Lbs.	Rate. Dols.	Rate. Cts.	Totals. Dols.	Totals. Cts.	Grand totals. Dols.	Grand totals. Cts.	Cost per Ton. Dols.	Cost per Ton. Cts.
		Ingots—Mill	1753	327								
		" Hammer	466	1830								
1	668		2219	1547	25	705			57065	79	33	370
		Wages—Rail-making	....	....	....	....	467	83				
		" Repairs	....	....	....	....	863	45				
	831	Boiler coal	634	448			1427	06	5334	68	3	236
	856	Producer-coal	801	448			1399	90				
			1295	896					2826	56	1	651
		Gannister	44	2456	5	708			253	09		147
		Wrought-iron	....	....	....	....	....	....	76	91		044
		Bricks and clay	....	....	....	....	....	....	10	00		006
		Castings	....	....	....	....	....	....	906	30		530
		Rolls	....	....	....	....	....	....	427	50		250
		Stores	....	....	....	....	....	....	60	73		352
		Repairs	....	....	....	....	....	....	215	75		125
		General charges	....	....	....	....	....	....	800	00		456
		Tools	1	350	75	00	....	....	86	66		050
		Debentures, depreciation, etc.	....	....	....	....	....	....	850	00		496
									69654	00	40	780
		Deduct :										
	209	Crop-ends	154	660	18	00	2777	31				
		Hammer-scrap	90	217	15	00	301	46				
		Mill-scrap	2	280	15	00	31	88				
		Billets	23	1834	27	75	621	81				
	300	Blooms	156	381	31	25	4882	33				
		Slabs	26	1666	37	50	627	09				
		Blooms stocked	9	2016	37	50	332	75				
		Tools and forgings	1	1071	75	00	110	94				
		Scale and cinder	449	2128		625	281	25				
									9954	58	5	800
		Cost of rails	....	....	....	....	....	....	59700	32	34	980

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TABLE VI.

Cost of Making 1882 *tons* 2236 *lbs. of Bessemer Steel Rails.*

West Cumberland Iron and Steel Co.

Fortnight ending Feb. 24, 1877.

Ratio per ton. Tons.	Ratio per ton. Lbs.	Description.	Weight. Tons.	Weight. Lbs.	Rate. Dols.	Rate. Cts.	Totals. Dols.	Totals. Cts.	Grand totals. Dols.	Grand totals. Cts.	Cost per ton. Dols.	Cost per ton. Cts.
		Ingots—Mill	1980	46								
		" Hammer	358	1498								
	542		2338	1544	24	75			5788	56	30	738
		Wages: Rail-making	....	....	....	....	....	....	4764	91	2	530
		" Repairs	....	....	....	....	....	....	761	35		404
	708	Boiler-coal	595	1792			1340	56				
	820	Producer-coal	689	224			1431	25				
	1528		1284	2016					2791	81	1	483
	53	Gannister	45	392	5	70			257	88		136
		Wrought-iron	....	....	....	....	....	....	186	60		099
		Bricks and clay	....	....	....	....	....	....	10	00		005
		Castings	....	....	....	....	....	....	149	96		079
		Rolls	....	....	....	....	....	....	470	75		250
		Stores	....	....	....	....	....	....	533	66		283
		Repairs	....	....	....	....	....	....	235	37		125
		General charges	....	....	....	....	....	....	800	00		424
		Tools		1831	75	00			61	25		033
		Debentures, depreciation, etc.	....	....	....	....	....	....	850	00		452
									69756	13	37	041
		Deduct:										
	181	Crop-ends	152	170	26	85	2472	25				
		Hammer-scrap	21	1750	15	00	326	70				
		Mill-scrap	27	532	15	00	408	56				
	806	Billets	15	1750	47	25	430	05				
		Blooms	101	1624	31	25	3178	89				
		Slabs	5	2386	37	50	220	69				
		Tools and forgings		1491	75	00	49	92				
		Scale and cinder	85	1232		625	53	37				
									7129	49	3	785
		Cost of rails	....	....	....	....	....	....	62626	72	33	256

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TABLE VII.

Cost of Ingots and Rails.—Indirect Process.

Brown, Bayley & Dixon, Sheffield.

March 3, 1877.

	Weight.		Rate.		Cost per ton.	
	Tons.	Lbs.	Dols.	Cts.	Dols.	Cts.
Making ingots.						
Pig-iron	1	84	17	95	18	60
Spiegeleisen		224	29	90	2	98
	1	308	18	95	21	58
Coke		336	4	45		67
Refractories						43
Castings, moulds						30
Wages					1	34
Repairs						85
Steam						80
Department and establishment charges						84
					26	81
Cogging and finishing rails.*						
Ingots, as above	1	496	26	81	32	75
Loss (one heat)		75	26	81		89
Crop-ends					2	11
Cobbles						00
Rails defective					2	23
					27	50
Coal						66
Wages					1	94
Repairs, etc.					1	30
Steam						67
Department and establishment charges					1	33
					33	40

* Note.—This is done at one heat. The rolls and operations will be described and illustrated in a report which will shortly follow.

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Fig I

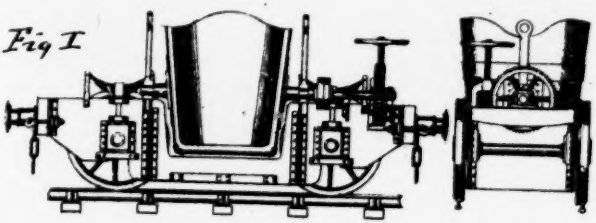
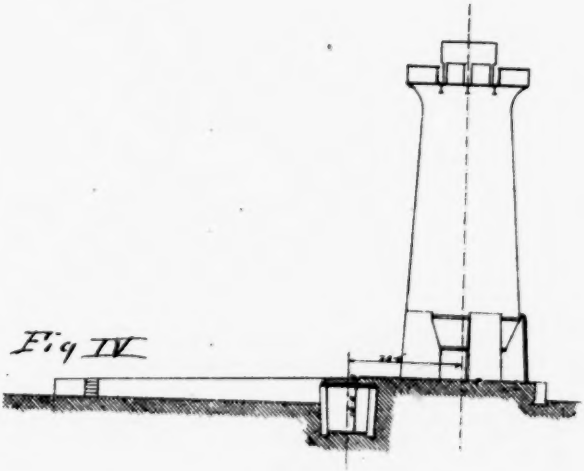


Fig IV



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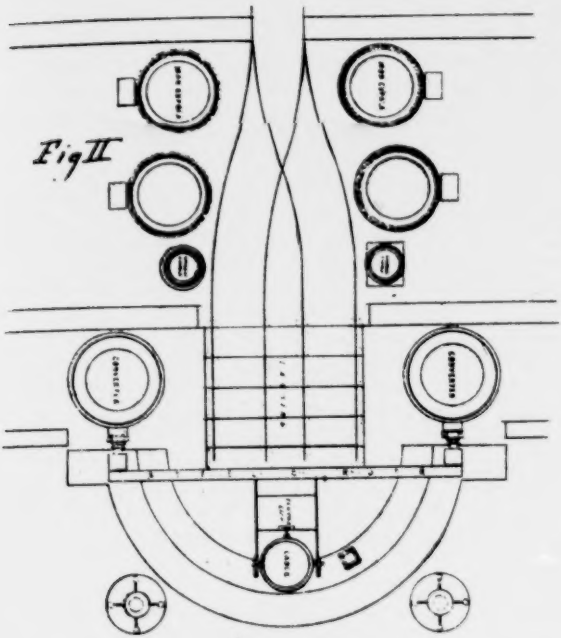

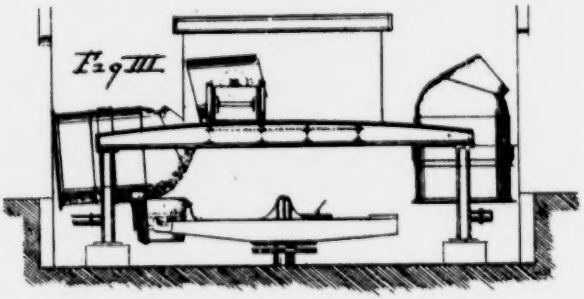

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the iron works in a cutting about 9 ft. deep at the base of the line of the pig beds, inside the foundry wall. Into this two or three wagons are shunted at a time; they are of simple design, and specially arranged for the transportation of the molten metal; they each have in the centre a ladle capable of carrying, if necessary, 11 tons or 12 tons, of metal, though about 8 tons is the usual quantity. Formerly the ladles were placed at one end of the wagon, and were balanced by weights at the other end; but the new design works better, and is of course much lighter. The metal is run from the furnace the whole length of the pig bed down an ordinary channel in the sand, to a point where there is a movable spout, over which the molten iron falls into the ladle. If desired the whole charge need not be taken from one furnace alone, but a mixture of
1206 the products of different furnaces may be made. When sufficient iron is in the ladle the channel is stopped, and the rest of the cast is allowed to run in the usual way for the manufacture of pigs. No difficulty is experienced as to the chilling of the molten metal; a small quantity of coal dust is sprinkled over the top, and the iron arrives at the steel works without any injurious loss of temperature. From the twelve furnaces the molten iron travels about a mile to the steel works, having to run to a junction, but from the two isolated furnaces the distance traversed is nearly two miles, and even in this length of journey no inconvenience has been experienced by the metal becoming cold.

It will be remembered that one of the most interesting discussions at the 1874 meeting of the Iron and Steel Institute was in reference to the practicability of transporting the molten iron from the blast furnaces to the Bessemer converter. The system had been even then tried, and had succeeded, on the continent, but in 1874 it was believed that, at least in England the process would be too hazardous. Even if the practical mechanical difficulties could be overcome at those works originally designed for the old system, it was considered by most of the steel-makers that it would be impossible to obtain constant results from the blast furnace, and to make steel from iron, the nature of which was unknown, would be too dangerous a leap in the dark. Within the last half dozen years, and within a mile of the scene of the discussion, the question has been practically settled on a scale of the greatest magnitude. Thirteen of the Barrow furnaces are now in blast, and the yield is over 6,000 tons per week; of this quantity more than a third goes to the steel works, and now none is in the form of pigs, unless to fulfill some order where reheated iron may have been stipulated. In the regular working it is known beforehand what will be the quality of the iron, and there has been no difficulty in this respect. Doubtless the large number of furnaces at Bar-
row is a great advantage, as if any of them are
1207 temporarily not in good working order, the iron for the converters can be obtained equally well from other furnaces. It is quite possible that a small works, with not more than two blast furnaces, more or less serious inconveniences might arise by the temporary derangement of one or both furnaces, which could only

be effectually guarded against by heavy stocks of pig iron, and much extra plant in cupolas, &c., which would mean a large amount of capital usually lying idle."

"DEFENDANT'S EXHIBIT MARYLAND STEEL COMPANY DISCONTINUANCE."

In the United States Circuit Court, District of Maryland.

THE CARNEGIE STEEL COMPANY, LIMITED,
vs.
THE MARYLAND STEEL COMPANY and F. W. WOOD, Receiver. } In Equity.

P. T. Dodge, Esq., solicitor for defendants in the above-entitled cause.

DEAR SIR: You will please take notice that on January 16th, 1897, at 10 o'clock a. m., or as soon thereafter as counsel can be heard, we shall present to the court the annexed affidavit of George Lauder, and shall move the court to order that the bill herein be dismissed without prejudice.

Very respectfully, BAKEWELL & BAKEWELL,
Solicitors for Complainant.

Service of the foregoing motion and of the papers named therein acknowledged this — day of January, 1897.

P. T. DODGE,
Solicitor for Defendants.

1208 In the United States Circuit Court, District of Maryland.

THE CARNEGIE STEEL COMPANY, LIMITED,
vs.
THE MARYLAND STEEL COMPANY and F. W. WOOD, Receiver. } In Equity.

Affidavit of George Lauder.

COUNTY OF ALLEGHENY, } *ss:*
State of Pennsylvania, }

Before me personally appeared George Lauder, who, being duly sworn, says that he is associated in the complainant company; that he is informed and believes that the defendant, The Maryland Steel Company, Limited, is not now engaged in the manufacture of iron and steel, nor in the use of the method of the patent in suit; but that for some time past, as deponent believes for a year or more, its works have been idle. It is, therefore, deemed by the complainant unprofitable and fruitless to pursue its suit further at present, unless and until it shall hereafter appear that the infringement of complainant's patent is renewed by the defendant.

GEORGE LAUDER.

Sworn to and subscribed before me this 4th day of January, 1897.
[SEAL.] G. I. HOLDSHIP,
Notary Public.

Order of Court.

This motion of complainant for discontinuance of this cause having come on for hearing, and counsel for complainant and defendant having been heard in opposition, the motion is granted, and it is hereby ordered and decreed that complainant's bill shall be and is hereby dismissed without prejudice, on condition that all evidence taken in the cause under stipulation or otherwise,
1209 may be used without prejudice in any future action which may be brought against the defendant, The Maryland Steel Company, for alleged infringement of the Jones letter- patent No. 404,414.

It is further ordered that the complainant shall pay to the defendant the costs of the suit to be taxed by the clerk.

THOMAS J. MORRIS, *Judge.*

January 16th, 1897.

UNITED STATES OF AMERICA, }
District of Maryland. }

I, James W. Chew, clerk of the circuit court of the United States for the district of Maryland, do certify that the foregoing are true copies, respectively of the original motion for leave to dismiss affidavit of George Lauder and order of court thereon, now on file and remaining among the proceedings in the above-entitled cause.

In testimony whereof, I hereunto set my hand and affix the seal of said court this 20th day of January, 1897.

[SEAL.] JAS. W. CHEW, *Clerk.*

"DEFENDANT'S EXHIBIT HOLLEY WILL."

I, Alexander L. Holley, of the city of Brooklyn, county of Kings and State of New York, being of sound disposing mind and memory, do make, publish and declare this my last will and testament.

1st. I revoke all other wills by me heretofore made.

2d. I give, devise and bequeath all property by me owned at the time of my death of every kind and nature whatsoever except as hereinafter mentioned, to my beloved wife, Mary H. Holley, for her own use and benefit forever.

3d. I give and bequeath my engineering library and the cases containing the same and also my engineering drawings and tracings and the cases in which the same are contained to the Rensselaer Polytechnic Institute at Troy, New York and direct
1210 that the said library and cases be delivered to said institute immediately upon my decease, but that my said wife, Mary H., retain possession and control of the said drawings and tracings and their cases at her option during three years next following my decease and have the exclusive use and benefit thereof with the

right to make and vend copies of said drawings and tracings, to receive and retain as her own all the income, profit and emolument in any manner arising from the use, possession and control of said tracings and drawings.

4th. I constitute and appoint my wife, Mary H. Holley, and my friends, John M. Slade and John C. Wyman, the executrix and executors of this my last will and testament.

In witness whereof, I have hereunto subscribed my name, this 7th day of November in the year 1880.

A. L. HOLLEY.

Witness:
JAMES A. SKILTON.
F. G. SALMON.

The foregoing instrument was on the 7th day of November, 1880, subscribed by the testator, Alexander L. Holley, in our presence and at the time of such subscription declared by the said testator to be his last will and testament and thereupon, we, at the request of said testator, and in his presence and in the presence of each other, signed our names hereto as subscribing witnesses.

JAMES A. SKILTON,
646 *St. Marks Avenue, Brooklyn, N. Y.*
F. G. SALMON,
345 *Clinton Street, Brooklyn, N. Y.*

STATE OF NEW YORK, }
County of Kings, } *ss.:*

I, Joseph W. Carroll, clerk of the surrogate's court in and for the said county of Kings, do hereby certify that I have compared the foregoing copy of the record of the last will and testament of Alexander L. Holley, late of the city of Brooklyn, deceased, with the original record thereof now remaining in this office, and
1211 have found the same to be a correct transcript therefrom, and of the whole of such original record.

In testimony whereof, I have hereunto set my hand and affixed my seal of the surrogate's court, this 22d day of December, in the year of our Lord, one thousand eight hundred and ninety-six.

JOSEPH W. CARROLL,
[SEAL.] *Clerk of Surrogate's Court.*

Quotation from London Engineering Jan. 18, 1884, *Page* 56, *to be Accompanied by Cut.*

Stewart's cupola.

Constructed by Messrs. Thwaites Brothers, Bradford.

We annex illustrations of a new type of cupola and receiver designed and patented by Mr. Stewart and constructed by Messrs. Thwaite Brothers, of Bradford. Its salient feature is that it contains three zones of fusion, surrounded by as many rows of tuyeres

A B, C D, E F, Fig. 1 and 2, termed respectively lower, middle and upper zones. In the top row A B, each tuyeres is provided with a shut-off valve. These valves have their plugs connected together by pitch-chains, and are operated simultaneously by one handle. The rows of tuyeres are all inclosed in a circular belt, and opposite each tuyere is a cover provided with a colored mica disc. The cupola is arched over at the top G, and has an opening H, fitted with a damper door for the escape of the gases. It stands upon a cast-iron plate on four pillars, and is provided with a drop bottom. In the front there is fixed the receiver provided with a spout, and large enough to hold a very considerable quantity of melted iron. The stand pipes I I to convey the blast from the blower, are two in number, one on each side. The receiver is also connected with the pipe K and ejector valves M, in order to draw the surplus or waste heat from it and force it into the tuyere chamber; and by a simple arrangement of the ejector valve M, the blast can

1212 be turned into the receiver at or below the surface of the metal to refine the iron. It is claimed for this cupola that it melts its charge rapidly, with the minimum quantity of fuel and is not more expensive than the usual construction. There is an absence of flame at the top, carbonic acid gas alone escaping, without any combustible gases; and the work is done with great regularity and little trouble at the tuyeres. These cupolas are made of melting capacities from one ton to twenty tons per hour. That shown in our illustration is of about four tons capacity per hour, and takes a bed of coke of about 4 cwt., whereas in ordinary furnaces about 13 cwt. is the usual bed charge, thus giving an advantage of about 9 cwt. of bed coke. Its approximate dimensions are as follows: External diameter of shell, 4 ft.; total height from ground line 24 ft.; height from ground line to under side of air belt 5 ft.; depth of air belt 2 ft. 6 inches; diameter of air belt 5 ft. 6 inches; melting part of cupola 3 ft. 6 inches deep and 1 ft. 10 inches in diameter, widening out to an internal diameter of 3 ft. in the upper portion; thickness of lining at melting part 1 ft. 1 in., upper portion 4½ in.; internal diameter of receiver 3 ft. and depth 3 ft.; height of tapping hole from ground line 2 ft. 3 in. Figs. 3 and 4 show a vertical section and plan of a cupola with the space for the melted metal inside and near the base, in the ordinary manner. The arrangement of tuyeres, air belt, valves, etc., is the same as with an external receiver, with the exception of the ejector valve, which is not necessary in this case. The base of the cupola is securely fixed to a cast bed plate. The engraving shows the upper portion of the cupola wanting from the first joint above the air belt, as Messrs. Thwaites Bros. find it convenient in some cases to supply them in this form, in order to render them easy of transport, and the purchaser can complete them to his requirements. In practice a narrow-gu*a*ge line of rails, 15 in. wide, is used for rapidly and conveniently conveying the molten metal from these

1213 cupolas to any required mould by means of portable receivers, one of which is shown in Figs. 5, 6 and 7. It consists of a wrought-iron casing, firebrick lined, and mounted on a

neat angle-iron frame, supported and carried on flanged wheels of the same gauge as the portable rails laid around the foundry. To one axle of the carriage is fixed a worm wheel actuated by a worm and hand wheel, to permit of the easy transit of the receiver by hand, and to prevent its movement, etc., while the metal is being discharged. This receiver is also fitted with a spout for tapping, and with two plugged holes, one on each side of the arched cover, for charging and for the escape of gases. The advantage of these portable receivers is that any number of them can be used in running large castings, without interfering with the ordinary work of the overhead traveling crane. Figs. 8, 9, 10 and 11 are illustrations of the small valve fixed inside the air belt of the cupola, for the purpose of regulating the ingress of the blast through the top row of tuyeres to the upper zone of fusion in the melting part of the cupola, A B, Fig. 2. These valves are generally brought into operation when blowing the charge down.

The Journal of the Iron & Steel Institute.

Vol. II, 1891.

On the Elimination of Sulphur from Pig Iron.

Pp. 76–92.

By Joseph Massanez.

If in the acid and the basic Bessemer processes, the molten pig iron is taken direct to the converter from the blast furnace, there is the disadvantage that the running of the individual blast furnaces can hardly ever be kept so uniform as it is desirable should be the case in order to secure regularity in the converter charges. In the manufacture of Bessemer steel, the variable proportions of silicon and of carbon here come chiefly under consideration, whilst
1214 in the basic process it is chiefly the varying proportions of silicon and of sulphur; and in cases where either ores with variable percentages of phosphorus or puddle slags are treated, the varying proportion of phosphorus has also to be considered. This disadvantage of the irregular composition of the individual blast-furnace charges is obviated in a simple and effective manner by W. R. Jones' mixing process. In this process, as much iron from the various blast furnaces of a works as is sufficient for a large number of Bessemer charges—say from seven to twelve charges, or in other words from 70 to 120 tons of pig iron—is placed in a mixing vessel. Only a portion of the pig iron placed in the mixer is taken for further treatment for steel, whilst new supplies of pig iron are brought from the blast furnace. In this way homogeneity sufficient for practical purposes is obtained.

In the treatment of phosphoric pig iron, which is employed in the production of basic steel, it is, however, not sufficient merely to conduct the molten pig iron in large quantities to the converter in a mixed condition, but the problem here is to render the proportion of sulphur also independent of the blast-furnace process to such an

extent that the proportion of sulphur in the finished steel is so low that the quality of the steel is in no way influenced by it. The question of desulphurisation has, especially of late years, become of the utmost importance, at any rate for the iron industry of the continent. By the great strike of 1889, the German colliers have succeeded in greatly improving their wages; and with this increase in wages not only is there a distinct diminution in the amount of coal wrought, but unfortunately, the coal produced since then is raised in a much less pure condition than was formerly the case. Consequently, the proportion of sulphur in the coke has considerably increased. Whereas formerly this proportion did not exceed one per cent., it has now in many cases risen to *to* 1.8 per cent.; so that an unpleasant ratio exists between the wages of the workmen
1215 and the amount of sulphur in the coal raised. It is therefore not remarkable that, even when ores fairly free from sulphur are treated, it easily happens that a sulphuretted pig iron is obtained.

In order to effect satisfactorily desulphurisation, attention has been bestowed on the fact that iron sulphide is converted by manganese into manganese sulphide and iron. If sulphuretted pig iron, poor in manganese, is added in a fluid condition to manganiferous molten pig iron poor in sulphur, the metal is desulphurised, and a manganese-sulphide slag is formed. It may be urged that it does not seem necessary to effect the desulphurisation by means of the reaction of the manganese and iron sulphide outside of the blast furnace, as it is possible, by suitably directing the blast-furnace process, by the employment of manganiferous ores or highly basic slag, so to desulphurise the iron in the blast furnace itself that it would be unnecessary further to lower the percentage of sulphur. Every blast-furnace manager, however, will have observed that, even with every precaution in blast-furnace practice, pig iron will often be obtained with so high a percentage of sulphur as to render it useless for the Bessemer acid or basic processes. If the desulphurisation in the blast furnace is carried sufficiently far, it is always necessary to work the furnace hot, and thus to obtain hotter iron than is desirable for further treatment in the converter. On the other hand, the method of further desulphurisation outside the blast furnace, described in this paper, presents the double advantage that part of the blast furnace can be kept cooler, and thus lime and coke be saved, and that there is a certainty that no red-short charges are obtained in the treatment in the converter, while the pig iron passes to the converter at a suitable temperature.

A further advantage presented by the direct process described in this paper is that the Bessemer works, is independent of the time at which the individual blast furnaces are tapped, as the pig iron required for the Bessemer process can be taken at any moment
1216 from the desulphurising plant. In Hoerde, where the mixing and desulphurising process has for a considerable time been regularly in use, it has been found that all the chief difficulties formerly encountered in the method of taking the fluid pig iron direct from the various blast furnaces to the converter have been

obviated. At Hoerde the mixing and desulphurising plant shown in the diagram (plate XV) is employed. This apparatus holds 70 tons of pig iron. It is, however, advisable to have an apparatus of greater capacity, say, 120 tons. The apparatus has the shape of a converter, and the hydraulic machinery by which it is moved is simple and effective. An hydraulic pressure of eight atmospheres is sufficient to set it in motion. The vessel is provided with a double lining of firebricks of the same quality as those used for the lining of blast furnaces. This lining is gradually attacked only along the slag line, and does not require repair until it has been in use for some six weeks. Further repairs are then necessary every three weeks. Only the few courses of spoilt bricks are renewed, and for the repairs, including the cooling of the vessel, a period of two or three days is required. At the end of the week the vessel is kept filled, so that its contents suffice for the last charge to be blown on Saturday. On Sunday night the vessel is again filled. The consumption of manganese is very low; theoretically it is the quantity required for the formation of manganese sulphide, and in practice it has been found that this amounts to about 0.2 per cent. The proportion of manganese which the desulphurised pig iron coming from the vessel should contain is best kept at about 1.5 per cent., in order to render the desulphurisation as complete as possible. Thus, a mean proportion of 1.7 per cent. of manganese in the pig iron passing into the vessel is more than sufficient to effect a thorough desulphurisation. Indeed, 1.0 to 1.2 per cent. of manganese is sufficient to effect a satisfactory desulphurisation. For the extent of the removal of the sulphur, the temperature and the duration of the reaction are of importance. It has been found that if 1217 highly sulphuretted pig iron is poured from the blast furnace into the desulphurising vessel, 15 to 20 minutes are sufficient to effect the desulpurisation requisite for the steel process. The part played by the duration of the process is seen from the results obtained with the last charges, if the vessel is emptied at the end of the week without fresh pig iron being added from the blast furnace. If, for example, 60 tons of pig iron with 0.065 per cent. of sulphur remain in the vessel, the proportion of sulphur with the last charges falls to 0.03 per cent. The iron in the vessel remains sufficiently fluid for several hours. When necessary, a little wood is thrown in. It has been found quite unnecessary to obtain heat by passing and burning a current of gas above the bath of metal.

The great convenience and certainty presented by the method described in this paper will, in all probability, lead to its extensive adoption. As a matter of fact, several works are now occupied with the installation of this mixing and desulphurising plant.

Discussion.

Mr. George Lauder (Pittsburgh) said, although he had not any experience in the subject dealt with by the paper, particularly the desulphurisation of pig metal in the mxier, he had had considerable opportunities of observing the mixer itself as used for ordinary

Bessemer iron. They had found in the Edgar Thomson works great benefit from the use of the mixer. The principal benefit had been in the blast-furnace practice, and in this way: Before mixers were put in, the blast-furnace managers had been, so to speak, under fear of death from the steel-works manager, lest a metal should be produced that could not be blown. The mixer had removed that fear from the mind of the manager, who found that he could put through a considerable portion of "off" metal. Supposing one
furnace ran badly, if the others ran well, the bad metal
1218 would be put with the good, and it all went to the steel
works. He was of opinion, and his colleague agreed with him, that they were indebted largely to the use of the mixer for the magnificent blast-furnace practice brought before the institute at its meeting in New York by Mr. Gayley. With regard to the desulphurisation, having been at the Hoerde works a few days ago, he had had ocular demonstration on the subject, or nasal demonstration in passing round the mixers, where he was nearly choked with the sulphur fumes. It was a remarkable thing, and probably some of the skilled chemists present could explain how the desulphurisation took place. At the Edgar Thomson works they had no such experience, because they had scarcely any sulphur in the metal. They had, however, an experience which they did not expect, namely, that of desiliconisation, amounting to a considerable percentage. Their trouble was that they had not enough silicon. Most works were troubled with high silicon, in which case the mixer was a great advantage. In their own case the silicon was too low, and therefore the desiliconisation was rather a disadvantage.

Sir Lowthian Bell, F. R. S., said he would like to add his experience at Barrow to that which had fallen from his friend Mr. Lauder. They had there one of the mixers. Of course it was well known to any one who followed the action of the blast furnaces that, apparently without any cause known to those in charge, there was a considerable variation in the composition of the pig iron obtained. That observation was particularly applicable to the variations in the contents of silicon, which necessarily affected the future operation of the steel-makers. If they had too much silicon there would be too high a temperature in the converter, and if they had the silicon too low they would have too low a temperature. The consequence was an irregularity in the product, causing great waste of iron and an increased quantity of defective rails. He was bound to say
that since they had applied the mixer they found a consider-
1219 able improvement in this respect, but whether it was all due
to the mixer he was not prepared to say. The mixer held about 100 tons of iron, and as they ran ten tons out at one end they ran ten tons in at the other, so that practically they would have an average of ten furnaces, or of iron taken at ten different times. Since they had begun to use the mixer the "defectives," from whatever cause, had fallen to something like half of what they were before. The expense of working the mixer was little or nothing.

With regard to the disappearance of silicon it was quite true that there was a certain amount of that element removed in the mixer.

He thought that was easily accounted for. Its sides were more or less covered with a coating of oxide of iron, and besides that there was the transference of the metal from one vessel to another, which was quite enough, in his opinion, to account for the small disappearance of silicon which took place during the operation. Of course the value of Mr. Massenez's inquiries on the removal of sulphur was very great, and particularly so in Germany, where, as he was informed yesterday by Mr. Thielen, nine-tenths of all the steel now made there was made by the basic process. Out of twenty-two converters there were only two, he believed, now making steel by the acid process. That arose from the difference in cost between the ordinary Bessemer pig and basic pig. In Germany they had a great abundance of material requiring basic treatment, namely, iron stone coming from Luxembourg, and from the neighborhood of Nancy, in France, which enabled them to compete, and to compete successfully with Bessemer pig made from Bessemer ore of the ordinary description, and in consequence the basic process had taken root there far more extensively than it had done in this country. It might be—and possibly at no very distant period of time—that the price of Bessemer ore might run up in this country so as to equalize the two processes. Already a very important ameli-
1220 oration had taken place with regard to the profit arising from the practice of the basic process in the great value of the by-product, as slag might now be regarded; in point of fact, the removal of the phosphorus from the iron had given to the manufacturer the power of returning that phosphorus to the soil of the country, in respect to the importance of which too much could not be said, particularly in this country, where the waste of phosphorus from the soil was, from the number of inhabitants, necessarily very large. He entirely agreed with the principle laid down by Mr. Massenez. No doubt very great risk was run in the manufacture of basic pig in having a large quantity of sulphur in the iron where furnaces were driven at too low a temperature.

Many years ago, it occurred to him that the sulphur which is used in the manufacture of soda might possibly be recovered by producing what he called factitious pyrites, which in point of fact, was a reunion of the sulphur used with iron. The oxide of iron obtained by burning the natural pyrites was fused with soda waste, in a blast furnace of ordinary construction, and the sulphur there was taken up by the iron. In preparing the factitious pyrites, he observed that so long as the temperature of the furnace was kept low—much lower than that of an ordinary blast furnace for smelting ore—they got only sulphide of iron; but if the temperature was allowed to rise, which it did occasionally, then they had no sulphide of iron, but only metallic iron, containing a certain quantity of carbon, scarcely any silicon, but a very considerable quantity of sulphur. That experiment, practiced on a large scale, and for many months, entirely confirmed the observation made by Mr. Massenez in his paper with regard to the behavior of sulphur in uniting with iron in a blast furnace working at a low temperature.

Mr. J. E. Stead said that last week he tried a rather interesting

experiment of mixing ferro-manganese with sulphide of iron, melting them together in a crucible—an experiment that bore out the results stated by Mr. Massenez and Mr. Lauder. Melting
1221 together a hundred parts of ferro-manganese, containing about 78 per cent. of manganese and 13 per cent. of iron, with prate sulphide of iron containing about 70 per cent. of iron and 27 per cent. of sulphur—mixing them up in fine powder in a plumbago crucible—he found, when the fusion was complete, on the surface of the fused metal, a slag containing 56 or 57 per cent. of manganese and 28 per cent. of sulphur, and the ferro-manganese underneath containing about 13 per cent. more iron than before, an equivalent less quantity of manganese, and only 0.02 per cent. sulphur. The scoria on the surface had only 1 per cent. of iron, showing clearly that the reaction which took place was such as the author had described in his paper, namely, $FeS+Mn=MnS+Fe$. In other words, the manganese and iron simply changed places. It was clear then that manganese compounds, or iron containing manganese, especially those containing carbon, seemed to be incapable of dissolving, or absorbing, or retaining in solution, or in suspension, or combining in any way, with the sulphide of manganese, and that this substance naturally rose to the surface as a semi-infusible mass. He noticed that the slag on the table was almost identical in character with the slag he had obtained in his crucible experiment.

Mr. H. Bauerman asked whether the experiments recorded on pages 78 and 79 of the paper referred exactly to the same processes? If he remembered rightly, the experiments recorded on page 78 were obtained by desulphurising by the addition of high ferro-manganese melted; and, as he gathered from the paper, that was now done in a simpler manner by using different classes of blast-furnace iron—that was to say, an ordinary pig iron, and apparently a sort of low spiegel; that, of course, was a simplification of the process. He would therefore like to know whether the experiments on pages 78 and 79 represented the working of the same process, or some modification.

1222 The PRESIDENT: I am afraid we are not in a position to give you that information.

Mr. Bauerman said that if that were so—and he was speaking only hypothetically—these experiments, which were carried out pretty much in the same way as Mr. Stead's—that was to say, first desulphurizing, effected with high ferro-manganese—were very remarkable. According to the paper, it appeared to have been done just with ordinary current blast-furnace iron, and therefore that was a great simplification.

The PRESIDENT: I think Sir Lowthian Bell's observations bear that conclusion out completely.

Dr. E. J. Ball said it was difficult to criticise the paper, because the details were wanting. It might be of interest to the members to know that some three or four years ago Mr. A. Wingham and himself made a long series of experiments (Professor Roberts-Austen would remember them, because they were done in his laboratory),

with a view of ascertaining the conditions under which sulphur was reduced in the blast furnace. They then tried some experiments in the crucible, and they found, as was anticipated, that any conditions which involved oxidation caused the sulphur to remain in the metal. It was evident that if it was possible in any way to eliminate the sulphur, those oxidizing conditions had to be abandoned, and deoxidizing conditions substituted instead, when the sulphur came out readily. They tried the manganese method, which, he regretted to say, was not always successful. Sometimes with basic slag desulphurization was at least partially successful; at other times no sulphur at all came out; and Mr. F. W. Harbord, a member of the institute, had told him that he had come across a specimen of pig iron, containing 4 per cent. of manganese and 2 per cent. of sulphur, which, again, was rather an interesting circumstance in that direction. They found that by using alkalies alone they could nearly always bring down the sulphur from the percentage mentioned in the
1223 paper to about 0.1 per cent.; but it was very difficult to bring it down farther, except by long and repeated action. That led them to believe that sulphur existed in the iron in two forms—(1) readily reducible or removable sulphur, probably in the form of an iron sulphide; and (2) a smaller quantity combined with oxygen in some form, possibly dissolved sulphite. They were not able to prove this, but they found, by using a small proportion of some deoxidizing agent, such as cyanide, that "oxidized" sulphur could be readily removed. In view of Mr. Carulla's remarks, that it was always advisable that experiments should be made public, he might say, on behalf of Mr. Wingham and himself, that they would be pleased to submit the results of the experiment to the institute at its next meeting, should the council deem them acceptable.

Mr. W. Galbraith said he was surprised to hear that it was necessary to carry out experiments for the purpose of showing that sulphur could be eliminated in the presence of manganese. It was a fact which he had been thoroughly well aware of, and he thought that it had been pretty well known for some years. It was a fact, moreover, which in actual practice he had found to be always thoroughly reliable, even in spite of getting iron with 4 per cent. of manganese and 2 per cent. of sulphur. This iron may have been made from a blast furnace; but if it had been allowed to rest in a receiver, or passed through a cupola, the sulphur would have almost entirely disappeared. It appeared to him as if the process had been devised as a means of working direct to do away with cupola melting, and in that respect it served a useful purpose—that was, it did away with the necessity of the Bessemer manager being in absolute terror of getting bad iron from the blast-furnace manager. There was, no doubt, a little terror on both sides. The blast-furnace manager was in terror lest the steel-works manager complained of the iron and the steel-works manager was also in terror of
1224 getting bad iron from the blast-furnace manager—that was when working direct. The receiver, therefore, would serve the useful purpose of equalizing things all round.

It would be noticed, however, that the iron referred to in the paper contained about 1½ per cent. of manganese; that it was very low in silicon, and contained .15 or .2 per cent. of sulphur. There could be no doubt that such iron put into a receiver of the character described would lose its sulphur. Its universal application, however, was not quite clear. It was not an iron, for instance, which could be made very readily in this country, and it was only useful for the basic Bessemer process. For the basic Siemens process the manganese was much too high; and if they were to adopt that process, it would be found that the high manganese which was necessary would probably render the pig an expensive one. The practical objection seemed to lie in the risk of delay, in the cooling of the iron in the receiver, and also in the loss and the cost of plant. He did not see where it possessed any great advantage over melting iron in the cupola. If they melted, in a cupola, hematite iron containing .8 per cent. of manganese, the .1 per cent. of sulphur would fall down to at least .07. All that was necessary was to melt in the cupola a fairly manganiferous iron, or to add some spiegeleisen or ferro manganese. The sulphur would be eliminated in that way. It seemed to him to be a question whether working in that way would not, after all, be as cheap as using the plant referred to. If something were to go wrong in the Bessemer process, and all the iron were removed in the receiver, and a delay occurred, it might become a complicated and difficult matter to know what to do with it, and that serious loss would go a long way towards covering the expense of running in a cupola for a prolonged period. With the basic Siemens process, also, melting in a cupola would have the additional advantage that they could work with higher silicon.

A pig with .2 or .25 per cent. was a very unusual one to
1225 make direct from the blast furnace, and it was not always easy. If it came much higher from the blast furnace, the melting in the cupola would not only reduce the silicon, but it would also reduce the sulphur, if the manganese were fairly high. The question, therefore, seemed to hang on the universal use of the process, and also on its costs as compared with melting in a cupola.

Sir Lowthian Bell said he should like to say a few words to lay the hobgoblin just raised by Mr. Galbraith, who had spoken about melting in the cupola. The cost of receiving the iron in a mixer was said to be 1d. a ton, but he would double that amount, in order that there might be no mistake about the question just raised. It was, in fact, the mere labor of filling and emptying it. Supposing the calamity referred to by Mr. Galbraith were to arise in the Bessemer department, it would be an easy thing to run the whole of the iron out into pigs. But the difficulty very rarely happened, owing to the circumstance that there were very few Bessemer works with which he was acquainted that had not at least two converters, and it would be an extraordinary thing if both converters met with the accident referred to by Mr. Galbraith at one and the same time. With regard to the alternate of melting pig iron, what was the state of things? Pig iron could not be melted with a smaller loss than half a cwt. to a ton; indeed, he knew it was often not under 5 per

cent. Then there was the labor and other charges; so that instead of having 2d. per ton to deal, as in the case of the mixer, the cost of remelting iron was about 2s. 6d. a ton. Therefore, in spite of the calamities that might attend the process in the event of the accidents referred to, he should be inclined to stick to the mixer.

Mr. George Lauder said he endorsed what Mr. Massenez had said with reference to the size of the mixer. Instead of 70 or 80 tons, they ought to deal with at least 120 tons; and if more, so much the better. At the Edgar Thomson works there were two mixers
1226 of 80 tons each, and they were altogether too small. The production had run up immensely since they were put in three years ago, the product having shown an increase of from 800 tons of rails to about 1,300 tons per day.

(Postscript.—Since these remarks, the Edgar Thomson works have produced in twenty-four hours the remarkable output of 1,924 gross tons of rails, 70 lbs. section.—G. L.)

Mr. G. J. Snelus said that having recently visited the Barrow works, and seen the mixer in operation, he could bear testimony to the accuracy of what Sir Lowthian Bell had said, and also of the assertion of Mr. Lauder, that the evident tendency was towards the use of a larger vessel. Twelve years ago he made part of an apparatus for a large mixer, but, unfortunately, the late Mr. Edward Williams, who came to the works over him, stopped it, and there the plant was still lying. He had many a talk about the success of the operation with the late Mr. Holley, who assured him that there could be no difficulty in it in 1891. He was now pleased to find that these ideas had born- fruit. With regard to the elimination of sulphur, they were much indebted to Mr. Massenez for the information he had given. It was quite true that they all knew more or less that metallic manganese had the effect of removing sulphur, but until Mr. Massenez had put it in practice, he did not think it had occurred to any of them how to do it; so that every credit was due to him. He felt sure that Sir Lowthian Bell was perfectly right as to the use of the mixer instead of the cupola; and he was surprised at Mr. Galbraith's suggestion on the subject of melting in a cupola, because, while the addition of the manganese would undoubtedly remove some of the sulphur, the sulphur in the coke would go to neutralize the operation. It had been found that whatever sulphur there was in the coke in the cupola went into the iron; but if there was a certain amount of manganese there, it was apparently corrected, and if it could be removed without the
1227 coke, and without the cost of 2s. 6d. per ton for melting, there could be no doubt as to which was the best operation.

Mr. R. A. Hadfield said he desired to mention a rather curious circumstance in connection with the manufacture of manganese steel, in which one would expect to find the sulphur entirely eliminated; but for some reason, of which he could not offer any satisfactory explanation, it was found that the sulphur was not reduced. It was contrary to the experiments mentioned by Mr. Massenez. His firm found the sulphur practically the same after the addition of manganese as before. This seemed a peculiar fact. The alloy

referred to was certainly not pig iron, but an alloy of iron and manganese with a little carbon; still, it was a curious circumstance that the sulphur was not eliminated. They certainly often noticed during the pouring operation a strong odor of sulphurous acid, but the analysis clearly showed that the sulphur was not in any way reduced. One would certainly expect it to be just the opposite, judging from the results in the case of ferro-manganese. He might mention that twenty years ago Dr. Percy pointed out that Caron, the metallurgist, found that by adding metallic manganese, by simple fusion with cast iron, containing as much as 1½ per cent. of sulphur, he reduced it to 0.1, 0.8, and 0.07 per cent. The discovery, therefore, was not a new one, but their thanks were due to Mr. Massenez for pointing it out in so practical a way, and for the particular apparatus employed.

The president said that the importance of the paper of Mr. Massenez has been illustrated by the valuable remarks which it had elicited, especially by those from Sir Lowthian Bell and Mr. Lauder, and he was quite sure that the members would desire to pass a cordial vote of thanks to Mr. Massenez for his communication.

A vote of thanks was tendered Mr. Massenez for his paper.

1228 Mr. Massenez writes to say, in reply to Mr. Bauerman's inquiry, that the results recorded in his paper were obtained with ordinary pig iron, containing an average of 1.75 of manganese.

COMPLAINANT'S EXHIBIT DURFEE PATENT NO. 114,277.

DEPARTMENT OF THE INTERIOR,
UNITED STATES PATENT OFFICE.

To all persons to whom these presents shall come, Greeting:

This is to certify that the annexed is a true copy from the records of this office of the letters patent granted Zohette S. Durfee, May 2, 1871, number 114,277, for improvement in the manufacture of iron and steel.

Application filed Februery 15, 1871.

In testimony whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed at the city of Washington this 30th day of March, in the year of our Lord one thousand eight hundred and ninety-seven, and of the Independence of the United States of America the one hundred and twenty-first.

S. T. FISHER,
Acting Commissioner of Patents.

[SEAL.]

114,277.

UNITED STATES PATENT OFFICE.

ZOHETTE S. DURFEE, of New York, N. Y.

Improvement in the Manufacture of Iron and Steel.

Specification forming part of Letters Patent No. 114,277, dated May 2, 1871.

I, Zohette S. Durfee, formerly of Troy, but now of the city and county of New York, in the State of New York, have invented certain improvements in the manufacture of iron and steel and
1229 of alloys of various metals, and in the apparatus connected therewith, of which the following is a specification:

The first part of my invention relates to the manufacture of iron and steel by mixing molten pig iron and oxides of iron, and sometimes adding other matters, and, after the mixture, treating the compound in suitable furnaces; and the accompanying drawing shows my apparatus for carrying out this and similar processes.

(Here follows diagram marked p. 1229*a*.)

An annular trough, *a*, supported on legs *b b*, is placed on the top of a furnace, or over an ingot mold, into which it may be desired to run the compound to be made and treated. This trough is provided with several spouts, *c c*, which converge toward each other. Above the trough is a hopper or large funnel, *d*, whose outlet, *e*, is immediately over the focus of the streams of metal to be run out of the spouts, *c c*, and this hopper may be supported by braces attached to the trough *a*, or as shown in the drawing herewith, or in any convenient manner. In the hopper is a feeding screw, *f*, which is intended to work so that no ore will run through the pipe *e* except when the screw is turned.

In operating my process a suitable quantity of pulverized ore is placed in the hopper and the screw put in motion. Molten pig iron is then run into the trough *a* by the runner *g*, or from a casting ladle, and as the ore is delivered from the pipe *e* it is taken by the convergent streams of iron from the spouts *c c* and carried down into the furnace or mold thoroughly and evenly mixed with the iron. By varying the speed of the screw or flow of iron the quantity of ore mixed with a given weight of iron can be regulated nearly at will. If the compound is run into ingot molds the ingots so made may be treated in ordinary heating furnaces or otherwise, as may be desired; but I prefer to run the compound directly into a furnace, as at *h*, through an opening in the roof *i*, said opening being closed after the furnace is charged. The compound can then
1230 be balled up and worked as puddled balls now are, or it can be melted into steel and tapped out at the tap-hole *k'*.

Improvement in the manufacture of Iron and Steel and of Metallic Alloys.

Inventor: Z. S. Durfee N.Y.

PATENTED MAY 2 1871

Fig. 1.

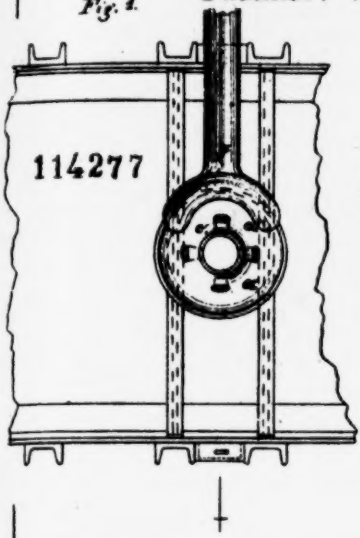
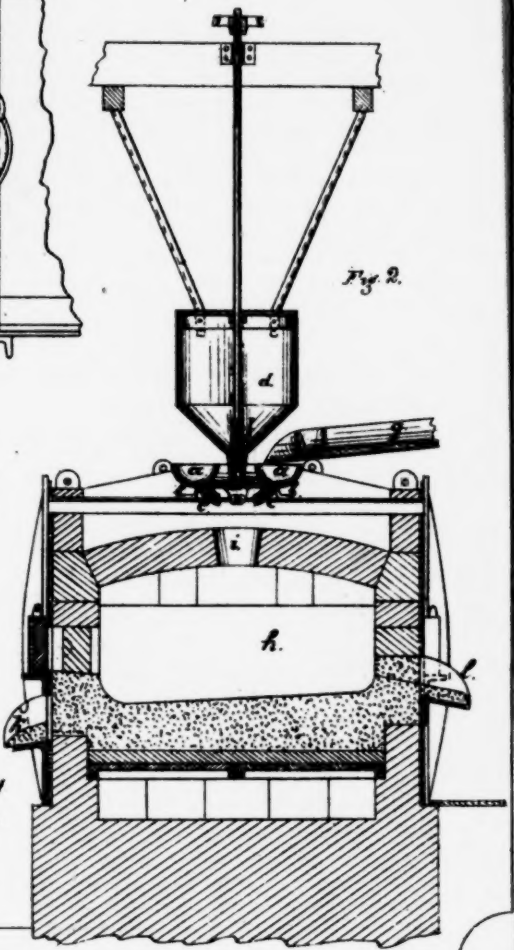


Fig. 2.



Carnegie Steel Co.
Cambria Iron Co. } p. 12 sq^t

Zohett S. Durfee
Inventor.

Chs. W. Ladd
Emil Heusner } Witnesses

When I propose to melt the compound into steel I allow a portion of the fluid iron to run through the trough *a* down upon the bed of the furnace before I start the screw to feed the ore, so as to have a bath of carburized metal for the compound to fall into. The furnace—which, by preference, should be a gas furnace—must be heated previously to running in the metal, and, in the course of the process, I would introduce along with the ore such fluxes or purifying substances as might advantageously be used therein; and the character of the steel can also be varied by adding, during the melting process, scraps of iron or steel, spiegeleisen, or other substances, as is now often practiced in melting steel.

I do not give any proportions of iron and ore to be used in this manufacture, as they will depend upon the richness of the pig iron in carbon and the purity and richness of the ore, as well as upon the character of the product required; and the mixtures can readily be made for any required product by those familiar with the metallurgy of iron and steel.

My apparatus and process are also adapted to the manufacture of alloys of iron and manganese, copper and manganese, iron and chromium, copper and chromium, and other alloys, in all of which manufactures I prefer to add the least refractory or most readily obtainable metal, in a fluid state, to the most refractory or rare metallic substance as it is found in ores or other compound state, substantially as just described in the manufacture of iron and steel.

In all these cases carbon in some form may be added to the pulverized ores to combine with any excess of oxygen in the mixture, and any desired fluxes may also be used; but I do not now propose to specify any particular mixtures.

The furnace *h* should have doors on both sides for working it and to admit of repairing the bottom easily, and a tap-hole, *l*, is also desirable for taking off any surplus slags.

1231 What I claim as my invention is—

1. The manufacture of iron and steel, and of various metallic alloys, by the combined apparatus and processes substantially as herein described.

2. The annular trough and feeding hopper combined together, and operated either with an ingot mold or a furnace, substantially as described herein.

ZOHETTE S. DURFEE.

Witnesses:
CHS. H. LADD.
EMIL FLUESNER.

COMPLAINANT'S EXHIBIT "COMMISSIONER'S REPORT."

(Offered May 23, 1897.)

DEPARTMENT OF THE INTERIOR,
UNITED STATES PATENT OFFICE,
WASHINGTON, D. C., *January* 31, 1896.

To the Senate and House of Representatives of the United States of America in Congress assembled:

I have the honor to submit the following report of the business of this office for the year ending December 31, 1895. * * *

Growth of Industrial Arts within the Past Twenty-five Years.

The expansion of the industrial arts under the stimulus afforded by the patent system is best set forth by the plain recital of facts. No single year will so well illustrate this as a more expanded view over a period of years. The industrial arts are a growth; inventions do not limit themselves in their bearing to so short a period as one year; therefore, it is here attempted to give a more extended survey of the advances in the practical arts during the period of the twenty-five years last passed, not because this period is marked off by any special epochs in the arts, but because it is a con-
1232 venient though arbitrary period with reference to the arrangement of facts, and as proved to be a period extraordinarily prolific in inventions throughout the world.

The difficulty in selecting material is obvious, and some unfortunate inferences may be derived from the method of treatment adopted; but to avoid mere generalization on the one hand and mere cataloguing of all patents on the other, it was determined to select as the tangible proofs of the various propositions of the text certain typical patents which illustrate the various stages of growth in the different arts.

It is recognized that those who practice a given art on a commercial and business basis are most competent to speak of the actual growth and development of the art. On the other hand the trained examiners of the Patent Office are well fitted to treat of the topic of invention in the domains assigned to them—from a somewhat different point of view, it is true, but yet usefully.

One object in attempting a somewhat general view of the industrial advance during the last twenty-five years is to afford landmarks to isolated inventors whose abilities are often misdirected to rediscovering, with praiseworthy originality and effort, and yet fruitlessly, improvements which only a cursory examination would show to be old, and to direct their attention to the true field of invention lying outside of the arts as they are already known and as represented in the accumulation of issued patents.

It is recognized that many imperfections must be apparent in any attempt, however studied and sincere, to truly set forth, in brief space this vast array of facts.

AGRICULTURE.

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FARMING.

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1233 PREPARATION OF FARM PRODUCTS.

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ALCOHOL.

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FIBERS.

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FRUITS & FOODS.

* * * * * * *

TOBACCO.

* * * * * * *

LIQUID.

* * * * * * *

ANIMAL PRODUCTS.

* * * * * * *

1234 CHEMISTRY.

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ENGINEERING, ELECTRICITY, AND TRANSPORTATION.

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ELECTRICITY.

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HOISTING.

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HYDRAULICS.

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FLUID EXPANSION DEVICES.

* * * * * * *

AIR AND GAS ENGINES AND PUMPS.

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1235 ORDNANCE, ARMS, EXPLOSIVES.

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STEAM-ENGINES.

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STOVES AND FURNACES.

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INDUSTRIAL MECHANICS.

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BRUSHING, CLEANING, AND POLISHING.

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GAS.

* * * * * * *

GLASS, POTTERY, AND PLASTICS.

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1236 LEATHER WORKING—SHOES.

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MINERALS.

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METALLURGY.

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Smelting processes.—In patent 116,604, July 4, 1871, Lewis discloses a process of smelting argentiferous lead ores and collecting the fumes resulting therefrom in bags. The fumes are subsequently treated. In patent No. 308,031, dated November 11, 1884, Crooke discloses a method of dissolving gold, silver, arsenic and antimony out of coarsely ground copper matte, by repeatedly immersing the ore in a bath of molten lead, which is maintained at a temperature below the fusing point of the matte. The first immersion serves to extract nearly all the gold and about 7 per cent. of the silver. In patent No. 386,629, July 24, 1888, Dixon discloses a means for smelting pyrites by introducing the crushed raw ore, mixed with fuel, into the body of the melted charge by means of an air blast. In patent No. 453,529, June 2, 1891, Austin discloses a means for smelting pyrites when it is mixed with lime and siliceous ore, by heating the lower part of the charge to a point where combustion of the sulphur can take place, and then introducing a blast of air heated to 1,000° F. By this process the use of carbonaceous material is dispensed with. In patent No. 478,110, July 5,
1237 1892, James treats zinc sulphide ores by calcining a part of the charge until it becomes oxidized, mixing this oxide with about half its weight of crude ore, and treating it in a reverberatory furnace until the mass becomes converted into zinc and sulphurous acid gas, the zinc passing off in fumes and being condensed. In patent No. 532,809, January 22, 1895, Nichols and James disclose a similar process for the reduction of refined copper, in which calcined copper matte is mixed with raw matte in such proportion that the sulphur and oxygen pass off as sulphurous acid gas. In patent No. 488,471, December 20, 1892, to Convers, is disclosed a method for treating certain zinc ores by heating, whereby the franklinite which may be contained therein becomes magnetic.

This is then separated by magnetic action from the willemite. The franklinite is then converted into zinc oxide in a Wetherill hearth, and the willemite reduced to spelter in a Belgian furnace. In patent No. 489,882, January 10, 1893, Thomson discloses a treatment of nickel ores or matte by smelting them with sulphide of an alkiline base, whereby nickel sulphide is formed, allowing this sulphide to settle by gravity from the copper, iron and alkaline salts, separating the resultant nickel sulphide and repeating the operation. In patent No. 489,881 of the same date, to Thomson is disclosed a method for smelting nickel ores and mattes with hydroxide or carbonate of an alkaline base, allowing the crude nickel to settle and separate by gravity, resmelting the same with alkaline metal sulphide, and allowing the nickel sulphide to separate by gravity. In patent No. 488,797, December 27, 1892, to Pearce is shown a roaster having an annular hearth with a horizontal slot in the inner wall, through which slot pass rotating arms, which serve to actuate the stirrers used to agitate the ore. The slot is kept closed by a ring carried round by the arms.

Leaching methods.—In patent No. 295,815, March 25, 1884, Russell discloses a method for treating ores containing gold and
1238 silver by lixiviating them with an aqueous solution of a double hyposulphite of sodium and copper. The precious

metals are dissolved out and are precipitated from the resultant clear solution by means of sodium or calcium sulphide. A way of cheapening the production of gold and silver has been found by MacArthur, No. 418,137, December 24, 1889. The ores of gold and silver are treated with a weak cyanide solution, thus dissolving out the precious metals, which may then be precipitated by zinc or by the electric current.

In patent No. 387,688, August 14, 1888, Low discloses a treatment of sulphide ores by roasting and leaching them with an aqueous solution of the sulphurous acid gas driven off. In patent No. 444,997, January 20, 1891, to West, is disclosed a process of converting roasted zinc ores into soluble sulphites by means of the joint action of steam and sulphurous acid gas from the roaster, the temperature of the gases being maintained below 180° F. The sulphide is leached out by water at a temperature also below 180° F.

The well-known process invented by Bessemer for refining iron now largely used in treating copper.—(See patent to Manhes, No. 456,516, June 21, 1891.) By this method the sulphur and other impurities are removed from the molten copper matte by blowing through it blasts of air. A process now commonly used in steel manufacture is that of patent No. 404,414, January 4, 1889, to Jones in which he described a means of getting a uniform product of metal by mixing together in a suitable receptacle batches of metal from different furnaces so that the mixture when drawn off will be the average of the different charges. A steel which has the property of hardening in the air and of producing very smooth castings was invented by Hadfield and is described in his patent No. 303,150, August 5, 1884. This steel is produced by alloying manganese with ordinary steel. Fine smooth castings are now also obtained by mixing with the molten iron or steel a little metallic aluminum.

1239 This is the Mitis process, patented by Wittenström in patent No. 333,373, December 29, 1885. The use of iron containing large percentages of phosphorus has been rendered practicable by processes introduced by Kunkel, No. 182,371, September 19, 1876, and Thomas, No. 218,334, August 5, 1879, which consists in lining furnaces with or by otherwise introducing into the molten metal lime generally obtained from magnesian limestone, in order that the phosphorus in the iron may combine with the lime and be removed in the slag. Nickel steel produced by alloying nickel with steel, a product possessing the qualities of great hardness and tenacity, is now largely used for armor plate and projectiles. (See patents Nos. 415,655 and 415,657, November 19, 1889, to Schneider).

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METAL WORKING.

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PAPER AND PRINTING.

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TEXTILES.

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GARMENTS.

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1240 WOOD-WORKING.

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STATIC APPLIANCES.

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INSTRUMENTS OF PRECISION.

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MUSIC, FINE ART, AND OPTICAL INSTRUMENTS.

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SAFES AND LOCKS.

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TRANSPORTATION.

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SHIPS.

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1241 *Conclusion.*

The foregoing history refers, as has been intimated, chiefly to patents which have been granted in the period from January 1, 1871, to December 31, 1895. But when the patents granted in a class or subclass are given all those which have ever been granted are included.

There have been many applications for valuable inventions filed within the same period and subsequently abandoned. Others filed within that period are still pending. Under the rules and practices of the office, which enjoin secrecy with respect to all unpatented

applications and caveats, these cannot be discussed, and they have not been referred to.

During the present month, there have been a number of important patents granted. To these also no reference has been made, for the reason that this report extends to the close of the past year. There are other inventions which have been brought into general use within the period of twenty-five years mentioned, for which patents have never been sought. To these also no reference has been made. Finally, no attempt has been made in this history to be guided in the selection of examples by the decisions of the courts. By following these, selection might have been made of many patents which are commercially valuable, but which are not as pointed illustrations of industrial advance as those which have been selected are believed to be.

Respectfully submitted.

JOHN S. SEYMOUR,
Commissioner.

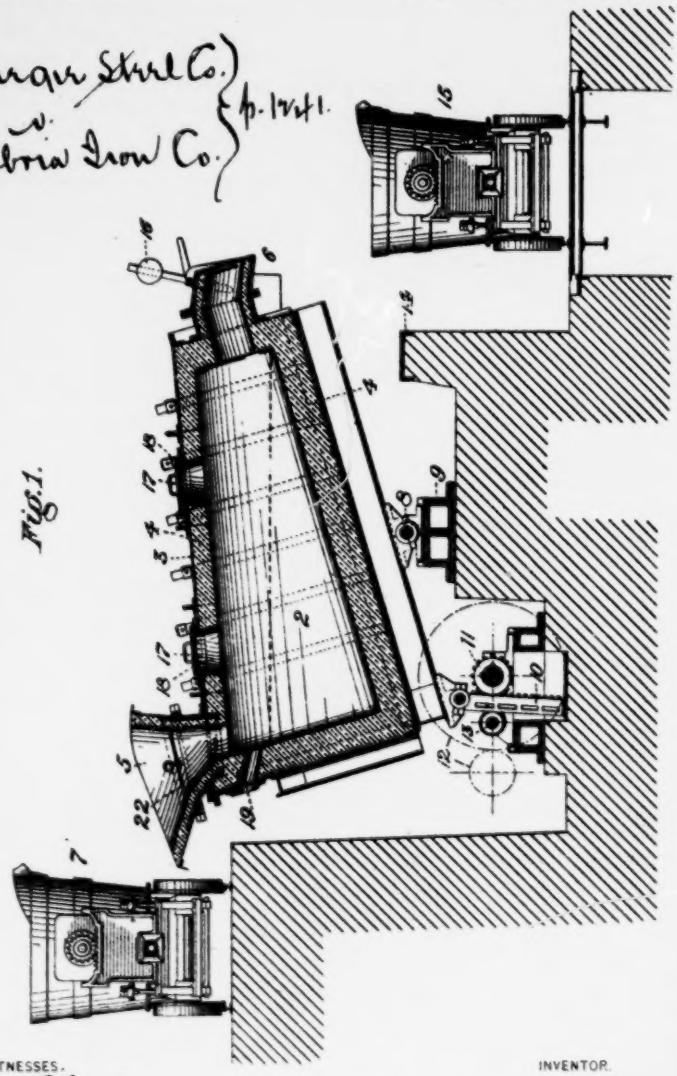
(No Model.) 2 Sheets—Sheet 1.

W. R. JONES.

METHOD OF MIXING MOLTEN PIG METAL.

No. 404,414. Patented June 4, 1889.

Carnegie Steel Co.
v.
Cambria Iron Co.
p. 1 of 1.



WITNESSES.

C. M. Clarke.
W. B. Corwin

INVENTOR.

William R. Jones
by W. Baxewell & Sons
his Attorneys

(No Model.) 2 Sheets—Sheet 2.

W. R. JONES.

METHOD OF MIXING MOLTEN PIG METAL.

No. 404,414. Patented June 4, 1889.

Carnegie Steel Co. v. Cambria Iron Co. } p. 1243

Fig. 2.

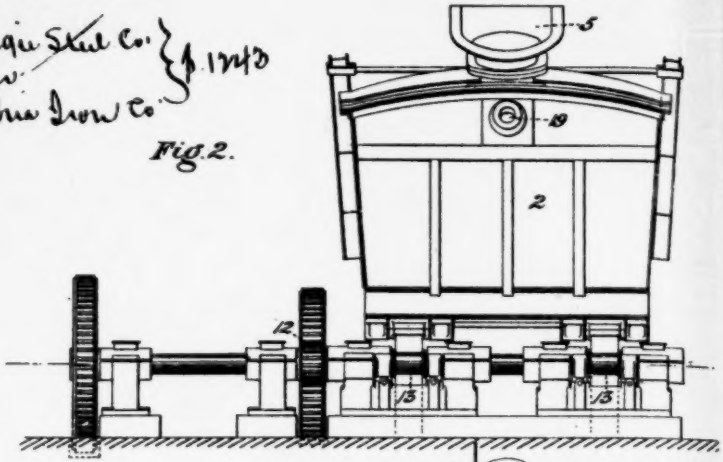
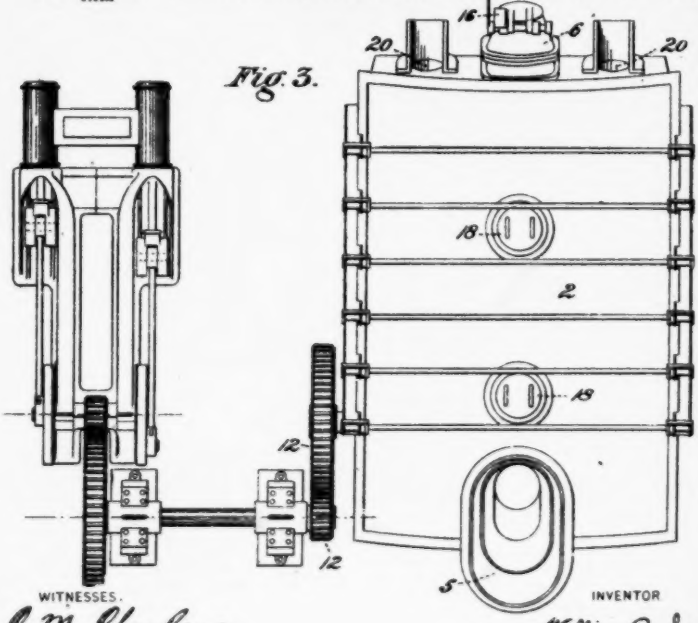


Fig. 3.



WITNESSES.

C. M. Clarke

W. B. Corwin

INVENTOR

William R. Jones

by W. Baxewell & Son

his Attorneys

1244 UNITED STATES PATENT OFFICE.

WILLIAM R. JONES, of Braddock, Pennsylvania.

Method of Mixing Molten Pig Metal.

Specification forming part of Letters Patent No. 404,414, dated June 4, 1889. Application filed October 31, 1888. Serial No., 289,672. (No specimens.)

To all whom it may concern :

Be it known that I, William R. Jones, of Braddock, in the county of Allegheny and State of Pennsylvania, have invented a new and useful improvement in methods of mixing molten pig metal ; and I do hereby declare the following to be a full, clear, and exact description thereof.

I shall describe my invention with reference to the accompanying drawings, in which—

(Here follow diagrams marked pp. 1242 & 1243.)

Figure 1 is a vertical longitudinal section of apparatus which I have invented for practicing my invention. Fig. 2 is an end elevation of the mixing-vessel and its actuating mechanism, viewed in the direction of the arrow A of Fig. 1. Fig. 3 is a plan view of the parts shown in Fig. 2.

Like symbols of reference indicate like parts in each.

The primary object of my invention is to provide means for rendering the product of steel-works uniform in chemical composition. In practice it is found that metal tapped from different blast-furnaces is apt to vary considerably in chemical composition, particularly in silicon and sulphur, and such lack of uniformity is observable in different portions of the same cast, and even in different portions of the same pig. The following table, giving the analyses of metal contained in different ladle-charges tapped from a blast-furnace at a single casting at the Edgar Thomson steel works, Braddock, Pennsylvania, will illustrate the fact: Ladle No. 1 contained silicon 4.15 per cent., sulphur .015 per cent.; ladle No. 2 contained silicon 4.07 per cent., sulphur .025 per cent; ladle No. 3 contained silicon 2.89 per cent., sulphur .030 per cent.; ladle No. 5 contained silicon 1.23 per cent., sulphur .120 per cent.; ladle No. 6 contained silicon 2.52 per cent., sulphur .061 per cent.; ladle No. 7 contained silicon .66 per cent., sulphur 143 per cent. The consequence of this tendency of the silicon and sulphur to segregate or form pockets in the crude metal is that the product of the refining process in the converters or otherwise in like manner lacks uniformity in these elements, and therefore often causes great inconvenience and loss, making it impossible to manufacture all the articles of a single order of homogeneous composition. Especially is this so in the process of refining crude iron taken from the

smelting-furnace and charged directly into the converter without remelting in a cupola, and, although such direct process possesses many economic advantages, it has on this account been little practiced.

For the purpose of avoiding the practical evils above stated I use in the refining process a charge composed not merely of metal taken at one time from the smelting-furnace but of a number of parts taken from different smelting-furnaces, or from the same furnace at different casts, or at different periods of the same cast, and subject the metal before its final refining to a process of mixing, whereby its particles are diffused or mingled thoroughly among each other, and the entire charge is practically homogeneous in composition, representing in each part the average of the unequally diffused and segregated elements of silicon and sulphur originally contained in each of the several parts or charges. By proceeding in this way not only is each charge for the refining furnace or converter homogeneous in itself, but, as it represents an average of a variety of ununiform constituent parts, all the charges of the converter from time to time will be substantially uniform, and the products of all will be homogeneous.

To this end my invention may be practiced with a variety of forms of apparatus—for example, by merely receiving in a charging-ladle a number of small portions of metal taken from several ladles or receiving-vessels containing crude metal obtained at different times or from different furnaces, the mixing being performed merely by the act of pouring into the charging-ladle, and other like means may be employed. I prefer, however, to employ the apparatus shown in the accompanying drawings, and have made it the subject of a separate patent application, serial No. 289,673, and, without intending to limit the invention to the use of that specific apparatus, I shall describe it particularly, so that others skilled in the art may intelligently employ the same.

My invention is not limited to its use in connection with converters, since similar advantages may be obtained by casting the metal from the mixing-vessel into pigs for use in converters, puddling-furnaces, or for any other uses to which pig-iron may be put in the art.

Referring now to the drawings, 2 represents the reservoir before mentioned. It consists of a covered hollow vessel having an outer casing 3, of iron or steel, which is suitably braced and strengthened by exterior beams and tie-rods, as shown in the drawings. The whole interior of the vessel is lined with fire-brick or other refractory lining, which should be of sufficient thickness to retain the heat of the molten contents of the vesssel and to prevent chilling thereof. The vessel is strongly braced and supported by braces and tie-rods, and may be of any convenient size, holding, say, one hundred tons of metal, (more or less,) and its shape is preferably such as shown in the drawings, being rectangular, or nearly so, in cross-section and an irregular trapezium in longitudinal section, one end being considerably deeper than the other. At the top of the deeper end, which I call the "rear" end, is a hopper 5, into

which the molten metal employed in charging the vessel is poured, and at the front end is a discharge-spout 6, which is so located that the bottom of the spout is some distance above the bottom of the vessel—say two feet in a hundred-ton tank, and more or less, according to the capacity of the vessel—the purpose of which is that when the metal is poured out of the spout a considerable quantity may always be left remaining and unpoured, and that whenever the vessel is replenished there may already be contained in it a body of molten metal with which the fresh addition may mix. I thus secure, as much as possible, uniformity in character of the metal which is fed to and discharged from the tank, and cause the fluctuations in quality of the successive tappings to be very gradual.

For convenient use of the apparatus I have found it best to so arrange it that it is adapted to receive its charges of metals from cars or bogies 7, which run on an elevated track at about the level of the normal position of the hopper 5, and to discharge its contents into similar cars or bogies 15 on a track below the spout 6. In order to facilitate the charging and discharging of the metal, the vessel is set on journals or bearings 8, which have their bearings in suitable pedestals 9, and its rear end is provided with depending rack-bars 10, which are pivotally connected with the bottom of the mixing-vessel 2 and are in gear with pinions 11, the shaft of which is connected by gearings 12 with the driving mechanism of a suitable engine. The pinions are held in gear with the rack-bars by idler wheels or rollers 13. As the journals or bearings 8 are located on a transverse line somewhat in advance of the center of gravity of the vessel, it tends by its own weight to tilt backward into the position shown in Fig. 1, but may be restored to a level position by driving the pinions 11, and thus raising the rack-bars 10 until the front part of the bottom of the vessel comes in contact with a rest or stop 14.

The mode of operation of the apparatus is as follows: When the vessel is in the backwardly-inclined position shown in Fig. 1, it is ready to receive a charge of metal from the car 7. Before introducing the first charge, however, the mixing-vessel should be heated by internal combustion of coke or gas, and when the walls of the vessel are sufficiently hot to hold the molten metal without chilling it it is charged repeatedly from the cars 7 with metal obtained either from a number of furnaces or at different times from a single furnace. The charges of metal introduced at different times into the vessel, though differing in quality, mix together, and when the vessel has received a sufficient charge its contents constitute a homogeneous molten mass, whose quality may not be precisely the same as that of any one of its constituent charges, but represents the average quality of all the charges. If desired, the commingling of the contents may be aided by agitation of the vessel on its trunnions, so as to cause the stirring or shaking of its liquid contents. The mixing-chamber being deeper at its rear than at the front end, as before described, and its normal position when not discharging metal for the purpose of casting being with the bottom inclined upward toward the front or discharging end, and the bottom of the

spout being situate above the bottom of the vessel at its forward end, it is adapted to receive and hold a large quantity of molten metal without its surface rising high enough to enter the discharge-spout.

The discharge-spout 6 is furnished with a movable cover operated by a weighted lever 16, which, when closed, serves to exclude the outside air and prevent a draft of air through the vessel and the consequent rapid cooling of the molten contents. If care is exercised in keeping the cover closed, the metal can be kept in a fluid condition for a long time, the heat being kept up by repeated fresh charges of molten metal, and, if necessary or found desirable, by burning gas introduced by a pipe or pipes into its interior.

After the vessel is properly charged, the metal is drawn off into the cars 15 from time to time, as it is needed, by opening the door or cover 16 of the spout 6 and driving the engine 12, so as to elevate the rear end of the vessel and tilt it forward, and thus to discharge any required amount of its contents in the manner before explained into the cars 15, which are transported to the converters, or the metal is cast into pigs or otherwise used. The tilting of the vessel does not, however, drain off all the contents thereof, a portion being prevented from escaping by reason of the elevated position of the spout 6, and as the vessel is replenished from time to time each new charge mixes with parts of previous charges remaining in the vessel, by which means any sudden variations in the quality of the metal supplied to the converter is avoided. Instead of discharging the metal into the cars 12 and carrying it in the cars to the converters or casting-house, the vessel 2 may be so situate relatively to the other parts of a furnace-plant as to deliver its contents immediately to the converters or other place where it is to be utilized.

1246–1251

I find it in practice very advantageous to employ two or more mixing vessels constructed substantially as I have described, and to draw a portion of each converter charge from each of the mixing vessels. My invention is, however, not limited to the employment of two or any specific number of such vessels.

I shall now describe, briefly, other parts of the apparatus which are desirable and important in its practical use.

At the top of the vessel 2 are man-holes 17, designed to permit of access to its interior for the purpose of repairing or fixing the lining. These holes are provided with suitable covers 18 to exclude cold drafts of air from entering the interior. There is also a hole 19 at the rear end of the vessel near the top, through which a rabble may be inserted for the purpose of assisting or accelerating the mixing of the molten metal, and at the other end, at the level of the bottom of the interior, there are holes 20, provided with suitable spouts to enable all the molten contents to be drawn off when it becomes necessary to do so. (See Fig. 3.) The holes 20 should be provided with suitable stoppers.

I claim—

1. In the art of refining iron directly from the smelting furnace, the process of equalizing the chemical composition of the crude

metal by thoroughly commingling or mixing together the liquid-metal charge and subsequently refining the mixed and equalized charge, substantially as and for the purposes described.

2. In the art of mixing molten metal to secure uniformity of the same in its constituent parts preparatory to further treatment, the process of introducing into a mixing receptacle successive portions of molten metal *ununiform in their non-metallic constituents*, (sulphur, silicon, &c.,) removing portions only of the composite molten contents of the receptacle without entirely draining or emptying the same, and successively replenishing the receptacle with fresh ununiform additions, substantially as and for the purposes described.

In testimony whereof I have hereunto set my hand this 9th day of August, A. D. 1888.

WILLIAM R. JONES.

Witnesses:
E. J. SMAIL.
W. BAKEWELL.

1254 UNITED STATES PATENT OFFICE.

WILLIAM R. JONES, of Braddock, Pennsylvania.

Apparatus for Mixing Molten Pig Metal.

Specification forming part of Letters Patent No. 404,415, dated June 4, 1889. Application filed October 31, 1888. Serial No., 289,673. (No model.)

To all whom it may concern:

Be it known that I, William R. Jones, of Braddock, in the county of Allegheny and State of Pennsylvania, have invented a new and useful improvement in apparatus for mixing molten pig metal; and I do hereby declare the following to be a full, clear, and exact description thereof.

I shall describe my invention with reference to the accompanying drawings, in which—

(Here follow diagrams marked pp. 1252 and 1253.)

Figure 1 is a vertical longitudinal section of my improved apparatus. Fig. 2 is an end elevation of the mixing vessel and its actuating mechanism, viewed in the direction of the arrow A of Fig. 1. Fig. 3 is a plan view of the parts shown in Fig. 2.

Like symbols of reference indicate like parts in each.

The primary object of the invention is to provide means for insuring uniformity in the product of a Bessemer steel works or similar plant, in which the metal from one or more blast furnaces is employed to charge the converters. The product of different furnaces or of the same furnace at different times varies in quality, the variation depending on the kind of ore employed and on many other conditions well known to those skilled in the art, so that when the converters are charged at one time with the output from one furnace and at another time with the output from another furnace or furnaces the manufactured steel lacks uniformity in grade. To avoid this, I employ suitably-constructed reservoirs or vessels, into which the molten metal from the blast furnaces is put, the vessels being of proper capacity to hold a considerable charge of metal from a single furnace or from a number of furnaces, and being adapted to retain the metal in a molten state for a sufficient time to enable the different charges to mix and become homogeneous. The advantage which I thus obtain in securing uniformity and homogeneity in the total product will be readily understood by those familiar with the operations of a steel-works and the frequent loss which is caused by the lack of such uniformity. Such apparatus possesses, also, an additional advantage in that it makes it possible to dispense with cupola furnaces for remelting the pigs preparatory to charging the converters. The metal may be tapped from the blast furnaces into ladles or trucks, carried to and discharged into

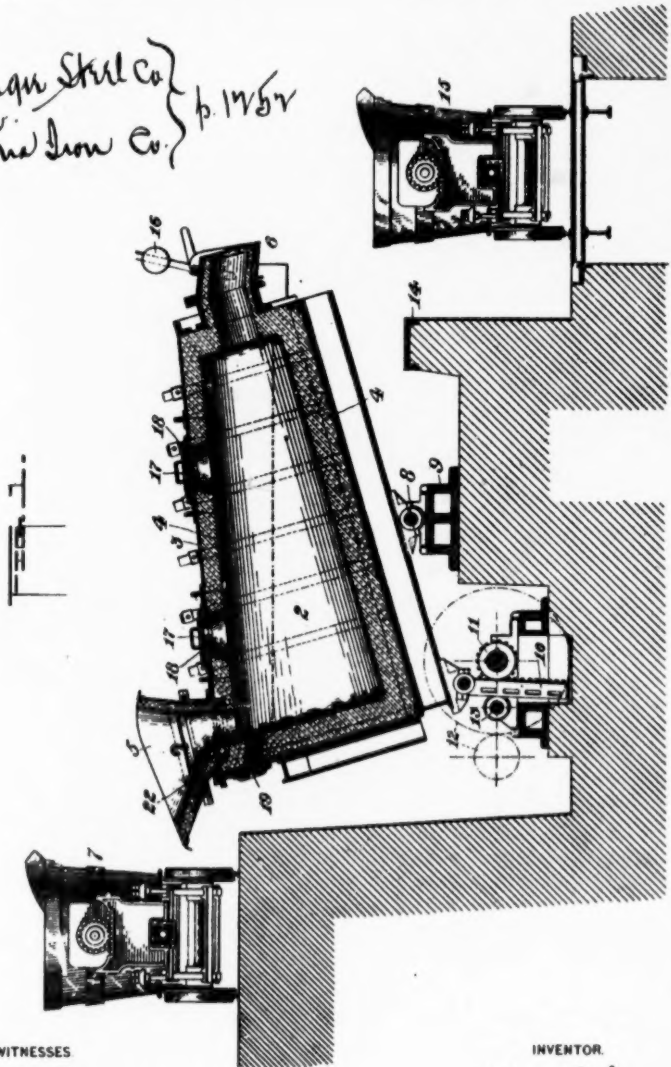
(No Model.) 2 Sheets—Sheet 1.

W. R. JONES.

APPARATUS FOR MIXING MOLTEN PIG METAL.

No. 404,415. Patented June 4, 1889.

Carnegie Steel Co. v. Cambria Iron Co. p. 1757



WITNESSES

N. B. Comstock

H. L. Gill

INVENTOR.

William R. Jones

by W. Bakewell & Son

his attorneys

Carnegie Steel Co. v. Cambria Iron Co. 5 p. 1253.

(No Model.) 2 Sheets—Sheet 2.

W. R. JONES.

APPARATUS FOR MIXING MOLTEN PIG METAL.

No. 404,415. Patented June 4, 1889.

FIG. 2.

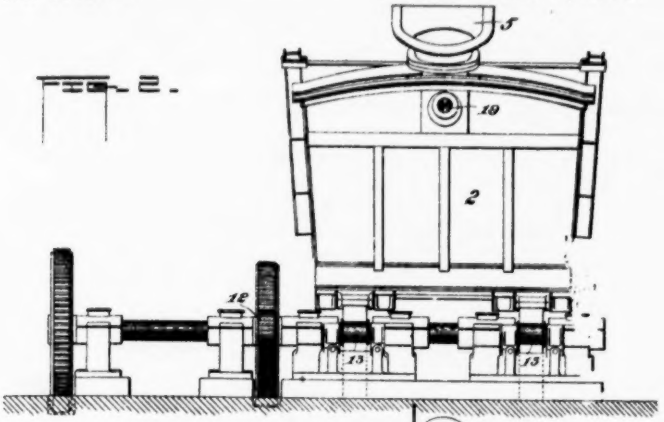
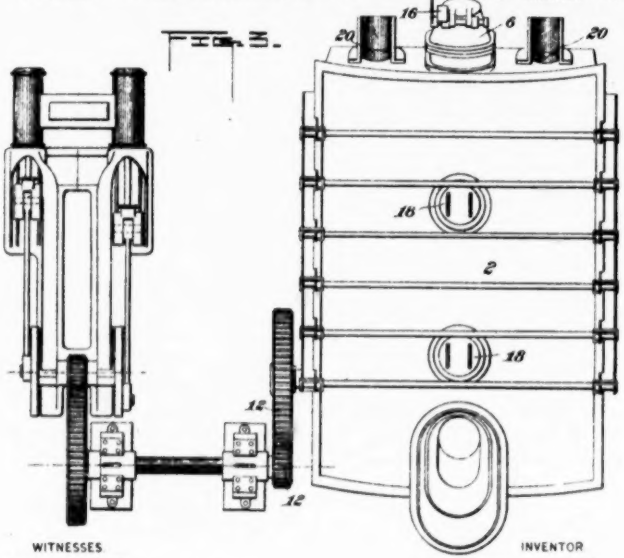


FIG. 3.



WITNESSES

W. B. Connin

H. L. Gill

INVENTOR

William R. Jones

by W. Bakewell & Sons

his attorneys

the mixing reservoir or vessel, and there retained in a molten state until sufficient metal has been accumulated to charge the converters. My invention is not, however, limited to its use in connection with converters, since similar advantages may be obtained by casting the metal from the mixing vessel into pigs for use in converters, puddling furnaces, or for any other uses to which pig iron may be put in the art.

Referring now to the drawings, 2 represents the reservoir before mentioned. It consists of a covered hollow vessel having an outer casing 3, of iron or steel, which is suitably braced and strengthened by exterior beams and tie-rods, as shown in the drawings. The whole interior of the vessel is lined with firebrick or other refractory lining, which should be of sufficient thickness to retain the heat of the molten contents of the vessel and to prevent chilling thereof. The vessel is strongly braced and supported by braces and tie-rods, and may be of any convenient size, holding, say, one hundred tons of metal, (more or less,) and its shape is preferably such as shown in the drawings, being rectangular, or nearly so, in cross-section and an irregular trapezium in longitudinal section, one end being considerably deeper than the other. At the top of the deeper end, which I call the "rear" end, is a hopper 5, into which the molten metal employed in charging the vessel is poured, and at the front end is a discharge-spout 6, which is so located that the bottom of the spout is some distance above the bottom of the vessel—say two feet in a hundred-ton tank, and more or less, according to the capacity of the vessel—the purpose of which is that when the metal is poured out of the spout a considerable quantity may always be left remaining and unpoured, and that whenever the vessel is replenished there may already be contained in it a body of molten metal with which the fresh addition may mix. I thus secure, as much as possible, uniformity in character of the metal which is fed to and discharged from the tank, and cause the fluctuations in quality of the successive tappings to be very gradual.

1255 For convenient use of the apparatus I have found it best to so arrange it that it is adapted to receive its charges of metals from cars or bogies 7, which run on an elevated track at about the level of the normal position of the hopper 5, and to discharge its contents into similar cars or bogies 15 on a track below the spout 6. In order to facilitate the charging and discharging of the metal, the vessel is set on journals or bearings 8, which have their bearings in suitable pedestals 9, and its rear end is provided with depending rack-bars 10, which are pivotally connected with the bottom of the mixing vessel 2 and are in gear with pinions 11, the shaft of which is connected by gearings 12 with the driving mechanism of a suitable engine. The pinions are held in gear with the rack-bars by idler wheels or rollers 13. As the journals or bearings 8 are located on a transverse line somewhat in advance of the center of gravity of the vessel, it tends by its own weight to tilt backward into the position shown in Fig. 1, but may be restored to a level position by driving the pinions 11, and thus raising the rack-

bars 10 until the front part of the bottom of the vessel comes in contact with a rest or stop 14.

The mode of operation of the apparatus is as follows: When the vessel is in the backwardly-inclined position shown in Fig. 1, it is ready to receive a charge of metal from the car 7. Before introducing the first charge, however, the mixing vessel should be heated by internal combustion of coke or gas, and when the walls of the vessel are sufficiently hot to hold the molten metal without chilling it it is charged repeatedly from the cars 7 with metal obtained either from a number of furnaces or at different times from a single furnace. The charges of metal introduced at different times into the vessel, though differing in quality, mix together, and when the vessel has received a sufficient charge its contents constitute a homogeneous molten mass, whose quality may not be precisely the same as that of any one of its constituent charges, but represents the average quality of all the charges. The mixing chamber being deeper at its rear than at the front end, as before described, and its normal position when not discharging metal for the purpose of casting being with the bottom inclined upward toward the front or discharging end, and the bottom of the spout being situate above the bottom of the vessel at its forward end, it is adapted to receive and hold a large quantity of molten metal without its surface rising high enough to enter the discharge-spout.

The discharge-spout 6 is furnished with a movable cover operated by a weighted lever 16, which, when closed, serves to exclude the outside air and prevent a draft of air through the vessel and the rapid cooling of the molten contents. If care is exercised in keeping the cover closed, the metal can be kept in a fluid condition for a long time, the heat being kept up by repeated fresh charges of molten metal and, if necessary or found desirable, by burning gas introduced by a pipe or pipes into its interior.

After the vessel is properly charged the metal is drawn off into the cars 15 from time to time, as it is needed, by opening the door or cover 16 of the spout 6 and driving the engine 12, so as to elevate the rear end of the vessel and tilt it forward, and thus to discharge any required amount of its contents in the manner before explained into the cars 15, which are transported to the converters, or the metal is cast into pigs or otherwise used. The tilting of the vessel does not, however, drain off all the contents thereof, a portion being prevented from escaping by reason of the elevated position of the spout 6, and as the vessel is replenished from time to time each new charge mixes with parts of previous charges remaining in the vessel, by which means any sudden variations in the quality of the metal supplied to the converter is avoided. Instead of discharging the metal into the cars 12 and carrying it in the cars to the converters or casting-house, the vessel 2 may be so situate relatively to the other parts of a furnace plant as to deliver its contents immediately to the converters or other place where it is to be utilized.

I shall now describe briefly other parts of the apparatus which are desirable and important in its practical use.

At the top of the vessel 2 are man-holes 17, designed to permit of

access to its interior for the purpose of repairing or fixing the lining. These holes are provided with suitable covers 18 to exclude cold drafts of air from entering the interior. There is also a hole 19 at the rear end of the vessel near the top, through which a rabble may be inserted for the purpose of assisting or accelerating the mixing of the molten metal, and at the other end, at the level of the bottom of the interior, there *there* are holes 20, provided with suitable spouts to enable all the molten contents to be drawn off when it becomes necessary to do so. (See Fig. 3.) The holes 20 should be provided with suitable stoppers.

I do not desire to limit myself to the precise form of the apparatus which I have shown and described, since many modifications in form and relative location of the parts may be made by the skilled mechanic; but

What I claim is—

1. An apparatus for receiving successive charges of molten metal from a blast furnace or furnaces and mixing the same previous to further treatment, consisting of an iron vessel having a refractory and heat-retaining lining, and being of substantially rectangular and trapezoidal shape in longitudinal cross-section, covered on top with a removable refractory-lined cover or covers, and furnished with suitable man-hole or man-holes, and having a charging hopper at or near the top at one end and a discharge opening
1256–1261 at the other end placed above the surface level of the fluid metal when the vessel is in its normal position, said vessel resting on a pivotal support or supports located nearer to the discharge end than the center of gravity of the vessel, in combination with mechanism for rocking the vessel on its pivotal support, substantially as and for the purpose hereinbefore described.

2. A mixing vessel for molten metal, said vessel having a refractory lining, a heat-retaining cover, a charging opening, and a discharging opening or spout, and provided with a pivotal support arranged forward of the center of gravity of the vessel, whereby the floor of the said vessel will normally incline downwardly from the discharge opening or spout toward the rear of the vessel, in combination with power mechanism for rocking the vessel on its pivotal support, substantially as and for the purposes described.

In testimony whereof I have hereunto set my hand this 9th day of August, A. D. 1888.

WILLIAM R. JONES.

Witnesses:
E. J. SMAIL.
W. BAKEWELL.

1263 UNITED STATES PATENT OFFICE.

JOHN W. NYSTROM, of Philadelphia, Pennsylvania.

Improvement in Furnaces for the Manufacture of Iron and Steel.

Specification forming part of Letters Patent No. 33446, dated October 8, 1861.

To all whom it may concern:

Be it known that I, John W. Nystrom, of the city and county of Philadelphia, in the State of Pennsylvania, have invented certain new and useful improvements in the construction, arrangement, and operation of furnaces destined for the manufacture of iron and steel; and I hereby declare that the following, taken in connection with the accompanying drawings, is a full, clear, and exact description of the same.

My invention consists, first, in the construction of a barrel-furnace in which one or more tuyeres are arranged at such an angle in relation to the curved bottom of the furnace that the blast shall be tangent, or nearly so, to the said bottom, and agitate the molten mass by passing along the interior or concave surface of the furnace, substantially in the manner and for the purposes hereinafter described; second, in the combination, with a barrel-furnace constructed and arranged essentially as described, of a front plate capable of removal, substantially as and for the purpose hereinafter set forth; third, in providing a barrel-furnace arranged and operated as hereinafter described with a friction-strap or its mechanical equivalent, to firmly hold and prevent shaking of the furnace during the operation of decarbonization, substantially as hereinafter specified; fourth, in the formation of a flue or chimney uniting the barrel-furnace with the cupola or blast furnace, essentially as hereinafter shown and described, so that particles of iron carried off with the air or gases or other volatile products may be returned to the furnace, and thus be utilized again; fifth, in so forming and arranging the outlet of a barrel-furnace constructed and operated as hereinafter described as that it shall occupy, when the furnace is in position to be emptied, the lowest part of the concave bottom.

To enable others skilled in the art to make and use my improvements, I shall now proceed to describe the construction, arrangement, and operation of the furnace, referring to the accompanying drawings, in which—

(Here follows diagram marked p. 1262.)

Figure 1 represents a cross-section of my improved furnace as combined with an ordinary cupola; Fig. 2, a longitudinal section of the same through the line A B in Fig. 1, and Fig. 3 a plan view of an arrangement of several furnaces with their cupolas.

The furnace F, it will be seen, is formed into the shape of a barrel

J. W. NYSTROM.

Making Bessemer Steel.

No. 33,446. Patented Oct. 8, 1861.

Carnegie Steel Co.
Cambria Iron Co. } p. 1180

Fig. 1

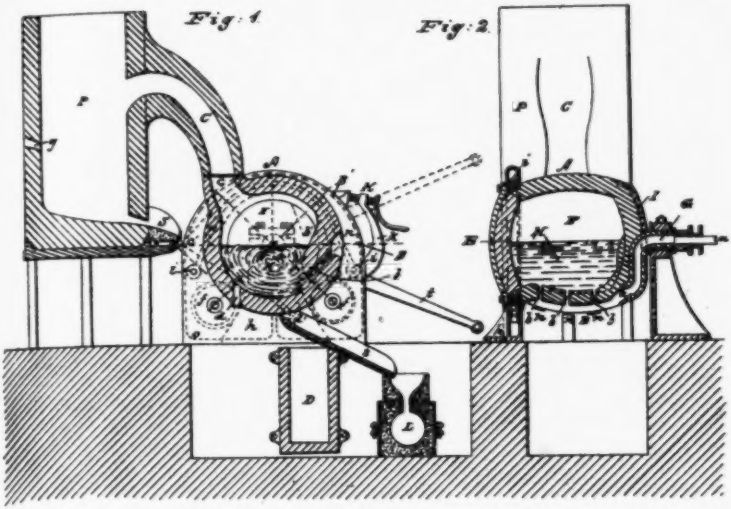
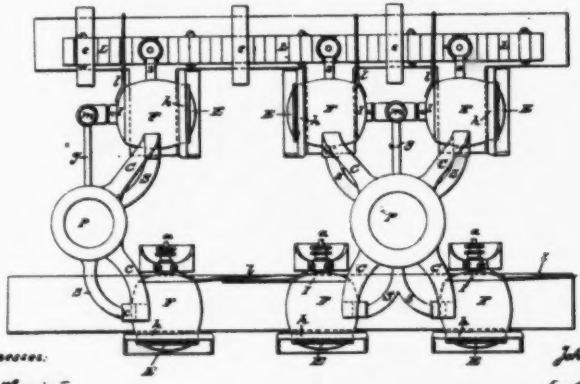


Fig. 2.

Fig. 3.



Witnesses:
W. H. Thomas
A. G. Thomas

Inventor:
John W. Nystrom by
A. Bleckley

placed horizontally and supported at one end by a hollow trunnion, G, resting in suitable bearings, while at the other end it is held in position by means of two friction-rollers, *f f*. The front or cap, E, the inside of which is lined with fire clay and brick, is screwed or clamped or otherwise securely attached to the end of the furnace, so that it may be easily removed when the inside of the furnace is to be built up, repaired, or cleaned out.

In the drawings, H represents the mass of molten cast-iron to be decarbonized on the well-known principle by blowing air into or through it. The air is conveyed from a suitable blowing-engine through the pipe and passages *a a*, and is blown into the furnace through the tuyeres *b b*, which are placed in an inclined position of about forty-five degrees, tangenting the curved bottom of the furnace. By thus arranging the tuyeres a more thorough and regular circulation is imparted to the mass of molten iron. The carbonic-acid gas formed in the furnace is conveyed off by the chimney C into the cupola or blast furnace P. Particles of iron that are carried off with the air, gases, or other volatile products engendered during the carbonization of the iron will be thus collected and utilized in the cupola or blast furnace, while additional heat for the melting of the cast-iron or the smelting of the ore will be attained. The frame *h* contains the friction-rollers *f f* and strap *i*, which are arranged in the front end of the furnace, the former to support that end of the furnace, and the latter, by being stretched by the lever and screw *k k* around the front end of the furnace against the friction-rollers *f f*, to keep it steady during the operation of blowing air into the molten metal. Other means may be resorted to, however, to prevent the violent shakings of the furnace, such as clamps, weights, wedges, screws, &c.; but I have described a simple and efficient device to effect the purpose. The outer shell of the furnace I prefer to make of wrought-iron, riveted to the back I.

In the shell of the furnace opposite the tuyeres are inserted removable glasses *n n n*, for the purpose of looking through 1264 into the furnace during the operation, and also for cleaning the tuyeres. The furnace is moved around its axis by means of lever *l*, fastened to the back I, as shown in the plan view, Fig. 3. By this lever the furnace is placed in the different positions required during the operation.

When the furnace is to be filled with molten iron, it is turned so that the mouth *c* comes to *c'* under the spout S. The iron may be thus run directly from the cupola or blast furnace into the furnace F.

In order to clean the furnace out from slag, &c., it is turned so that the mouth *c'* comes down toward the corner *o*, when part of the slag will run out, the remainder being removed by suitable tools or implements. The furnace may be turned by gearing, worm-screw, or other mechanism. It is intended here to turn the furnace by means of ropes and pulleys, the former fastened to the end of the lever *l*, while the latter is secured to some convenient place in or near the ceiling or roof of the foundry. When the iron is decarbonized, the furnace is turned so that the opening *d* comes to *d'*, in

which position it is allowed to remain for a few minutes, so that the slag and other light impurities may rise to the surface of the molten mass. The fluid metal is then let out through the aperature *d*, either directly into a mold or chill, D, or by the spout *s* to the mold L. The outlet *d'*, being at the bottom of the vessel, lets out the pure iron or steel first, while the slag and lighter impurities remain on the surface of the molten mass, thus producing a good, pure casting.

Fig. 3 shows how to arrange several furnaces, F, and cupolas P, for the purpose of casting large and long pieces. Any number of furnaces and cupolas may be employed in this way. On one side of the cupolas the blast is led through a pipe or column, *m*, into the furnaces F, and by the pipes *g* into the cupolas. The pit for casting large and long pieces branches off under the furnaces, as shown in the drawings. Boards *e e e* are placed for crossing the pit. This seems to be a good arrangement; but it can also be arranged with a long pit directly under the furnaces, as shown on the other side of the cupolas.

The operation is conducted in the following manner: The cast-iron is first melted down in the cupola P. The furnace F is turned by the lever *l*, so that the mouth *c* comes to *c'* under the spout S. When the cast-iron is melted, it is let out in the ordinary way and conducted by the spout S directly into the furnace F, until it is about half full, which will be indicated by the fluid mass being in the barrel-furnace on a level with the mouth *c'*. The spout S is then drawn aside, the blast turned on, and the furnace moved by the lever *l* until the mouth *c* butts up close to the chimney C. The furnace is now clamped fast to the friction-rollers, and the operation of decarbonizing the iron is continued for from five to fifteen minutes, according to the kind of iron or steel that it is intended to be obtained. The strap *i* is now loosened by the screw and lever *k k*, the furnace turned to its former position, when the outlet *d* will come to *d'*, through which the fluid iron or steel is either cast directly into a mold or chill, D, or is conducted by means of spout *s* into the mold L. The casting may then be taken directly to a steam-hammer or rolling-mill and forged in the same heat.

For very large castings it will be necessary to employ several furnaces, as shown in Fig. 3, when the same operation must go on simultaneously in all of them.

Having thus fully described my invention, what I claim, and desire to secure by letters patent, is—

1. The construction and arrangement of furnaces capable of rotation upon a horizontal axis, and having tuyeres so arranged in an inclined position that the blast enters the molten iron tangentially, or nearly so, to the curved bottom of such furnaces.

2. The combination, with a barrel-furnace constructed and arranged essentially as described, of a front plate capable of removal, substantially as and for the purpose herein set forth.

3. Providing a barrel-furnace arranged and operated as herein described with a friction-strap or its mechanical equivalent to firmly

hold and prevent shaking of the furnace during the operation of decarbonization, substantially as herein set forth.

4. In combination with a furnace capable of rotation, as described, and provided with a mouth for the reception of the molten metal from the cupola, the side chimney on the cupola so arranged that the said mouth shall come in juxtaposition with and convey the gases to the chimney, as described.

5. So forming and arranging the outlet of a barrel-furnace constructed and operated as herein described as that it shall occupy, when the furnace is in position to be emptied, the lowest part of the concave bottom.

In testimony whereof I have signed my name to this specification before two subscribing witnesses.

Washington, September 7, 1861.

JOHN W. NYSTROM.

Witnesses:

A. POLLAK.

EDM. F. BROWN.

1270 UNITED STATES PATENT OFFICE.

HENRY BESSEMER, of London, England.

Improvement in the Manufacture of Iron and Steel.

Specification forming part of Letters Patent No. 51398, dated December 5, 1865.

To all whom it may concern:

Be it known that I, Henry Bessemer, of Queen Street place, New Cannon street, in the city of London, in the Kingdom of Great Britain, have invented certain new and useful improvements in the machinery and apparatus employed in the manufacture of malleable iron and steel; and I do hereby declare the following to be a full and exact description of the same, reference being had to the accompanying drawings.

My improvements refer to the process of making malleable iron and steel by forcing currents of air through molten crude metal, as patented by me November 11, 1856; and consist in generating steam by the waste heat of the melting-furnaces, in the means and methods of admitting air to the converting-vessels, in the situation and moving of the converting-vessels, in the use and construction of apparatus for controlling the movement and operation of construction of converting-vessels and ladles, in the construction of ladles, and in certain arrangements and combinations of apparatus.

To enable this specification to be better understood I have included therein and in the accompanying drawings various matters which pertain to inventions heretofore made by me, upon which these improvements are additions.

To enable others skilled in the art to more fully understand and construct and use my invention, I will proceed to describe the apparatus and its operation.

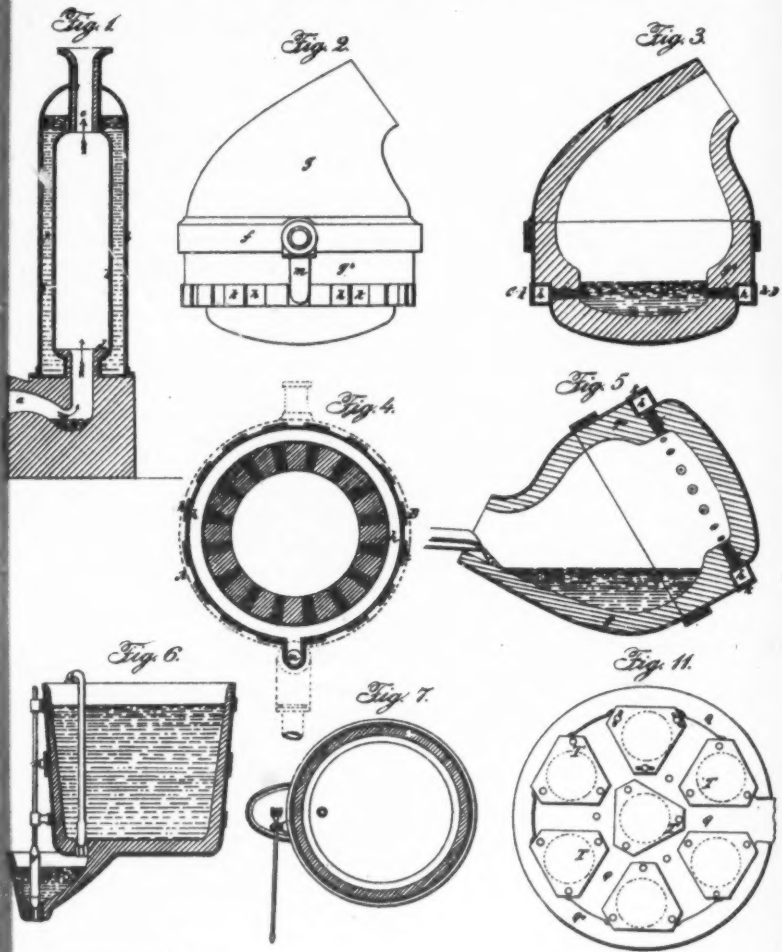
When it is desired to operate upon crude metal that has been formed into pigs of iron in the usual manner or which has previously been refined, I employ for the remelting of such metal a reverberatory furnace similar to those employed in melting iron for founding, but sometimes differing from them in having a second bed or hearth placed beyond the ordinary hearth or bank of the furnace and below the chimney, by which means two charges of metal differing from each other in quantity and quality may be melted in the same furnace without becoming mixed with each other. The chimney of the said furnace I prefer to consist of two vertical concentric cylinders made of boiler-plates, with a water-space between them, the inner cylinder being of a diameter much beyond that required to carry off the products of combustion, the inlet at the bottom and the outlet at the top of the said inner cylinder being contracted in size and lined with fire-bricks, so that the highly-heated vapors of the furnace are prevented from impinging forcibly on the metal surface of the boiler, whereby its durability is

5 Sheets—Sheet 1.

H. BESSEMER.

Making Bessemer Steel.

No. 51,398. Patented Dec. 5, 1865.



Carnegie Steel Co.
Cambria Iron Co. } p. 1265

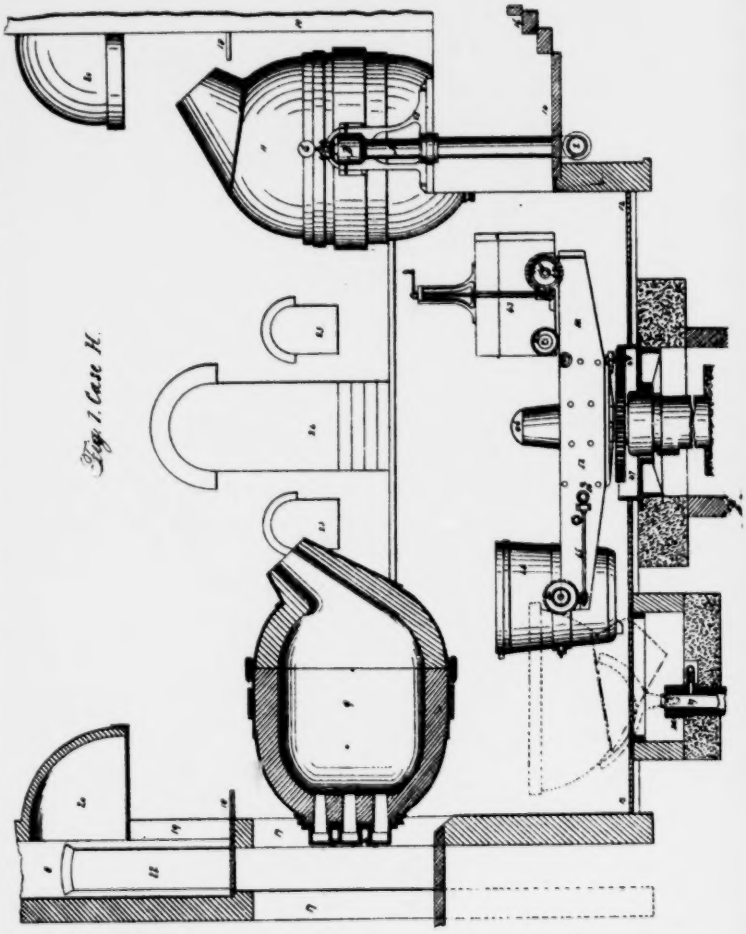
Inventor:
Henry Bessemer.
By B. & Sh. Coggins.
his Attys.

5 Sheets—Sheet 2.

H. BESSEMER.

Making Bessemer Steel.

No. 51,398. Patented Dec. 5, 1865.



Carnegie Steel Co. } p. 1766
v.
Cambria Iron Co. }

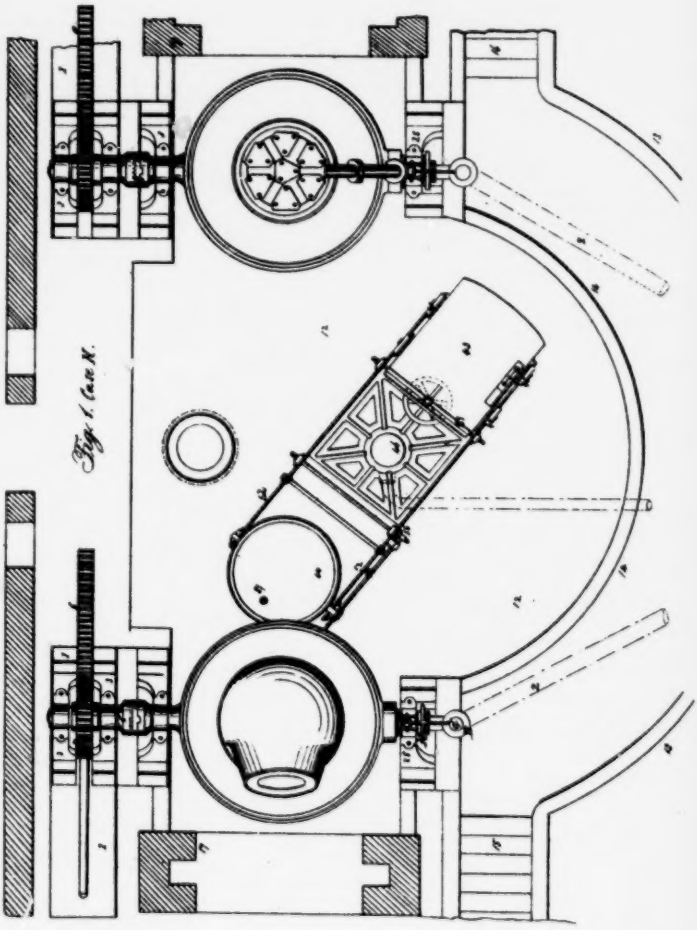
Inventor.
Henry Bessemer
By B. & Co. Dyer
his Attys.

5 Sheets—Sheet 3

H. BESSEMER.

Making Bessemer Steel.

No. 51,398. Patented Dec. 5, 1865.



Carnegie Steel Co.
v.
Cambria Iron Co. } p. 1267.

Inventor.

5 Sheets—Sheet

H. BESSEMER.

Making Bessemer Steel.

No. 51,398.

Patented Dec. 5. 186

Fig. 4.

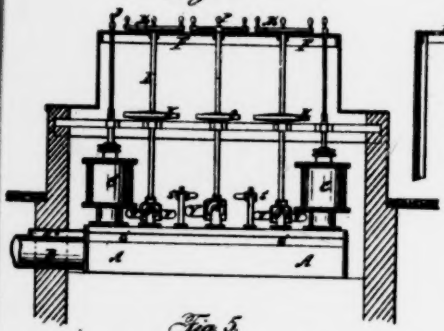


Fig. 8.

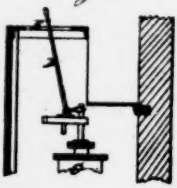


Fig. 6.

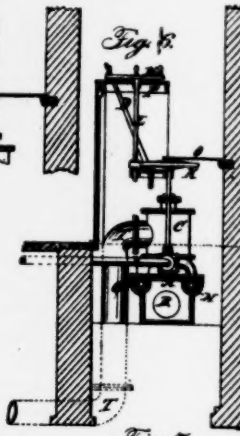


Fig. 5.

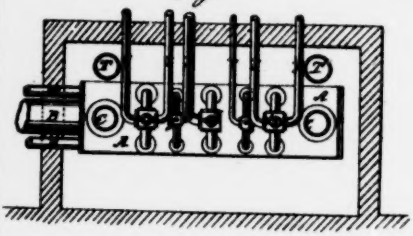


Fig. 7.

Fig. 10.

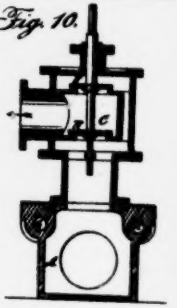


Fig. 3.

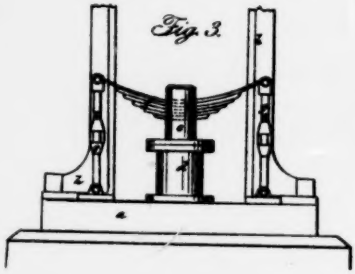
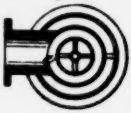


Fig. 9.



Carnegie Steel Co.
Tambua Iron Co. } p. 1268

Inventor.

Henry Bessemer
By B. & S. D. Bessemer
his Attys

5 Sheets—Sheet 5.

H. BESSEMER.

Making Bessemer Steel.

No. 51,398. Patented Dec. 5. 1865.

Case. H

Fig. 1.

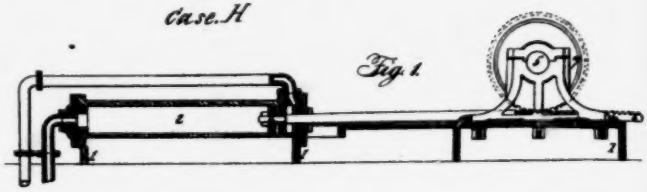


Fig. 2.

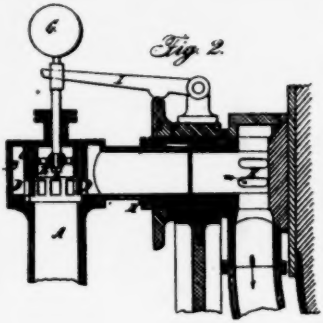


Fig. 8.

Fig. 9.

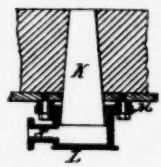


Fig. 12.

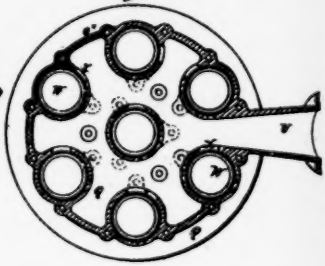
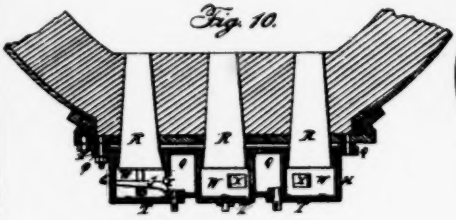


Fig. 10.



Carnegie Steel Co. v. Cambria Iron Co. } p. 1269

Inventor.

Henry Bessemer.
By B. & S. D. Coggeshall
his Attys

increased, while the utilization of the heat escaping from the melting-furnace will lessen the cost of manufacture by furnishing steam for driving the blast-engine or other machinery employed.

And in order that this arrangement of a steam-boiler in connection with the melting-furnace may be fully understood, I have shown a vertical section of the same on sheet A, figure 1, of the drawings hereunto annexed, where—

(Here follow diagrams marked pp. 1265 to 1269, incl.)

a represents the end part of the reverberatory furnace, on which is placed the vertical cylindrical boiler *b*, its lower end being made flat and stayed by vertical radial plates (not seen in the drawings) for the purpose of enabling the lower part to sustain the great internal pressure to which it is subjected. The contracted part *c* of the flue-tube is lined with fire-bricks, *d*, as shown, so as to conduct the highly-heated products of combustion into the enlarged part of the flue-tube b^x without allowing the flame to impinge forcibly upon the metallic surface of the boiler. The upper part of the flue-tube b^x is also contracted and lined with fire-bricks *e*, so that no part of the metal of the boiler-flue which is surrounded by steam shall be in contact with the flame or heated vapors at the furnace.

The boiler should be provided with the usual steam-pipes, water-supply pipe, and safety-valve, (not shown in the drawings,) and the outer and inner shell may be connected at intervals with stay-bolts in a manner similar to that employed in the construction of the fire-boxes of locomotive-engines.

Access to the interior of the boiler may be had through a manhole in the usual manner. The space between the flue-tube and the outer shell of the boiler I prefer to be such as will admit a workman, to clean the whole interior of the boiler when required.

The converting-vessels, in which the melted iron is converted into malleable iron or steel, are provided with axes on which they are moved by hydraulic apparatus, as shown in the drawings, or by any other convenient means, when required. Through one of these axes the air is conducted from a fixed pipe.

1271 It is of great importance to the successful working of the apparatus that the admission of the air to the vessel and its exclusion therefrom should never fail to take place whenever the vessel assumes certain positions both in its upward or downward movements. Otherwise the tuyeres may become stopped up with fluid metal or the metal may be blown out at the mouth of the vessel. To render the operation certain I employ a valve in the air-pipe near the axis of the vessel, and I fix onto the axis a cam which acts on a lever so placed as to open or shut off the air by the vessel's own motion, instead of moving the valve by the hand of the workman, as hitherto practiced.

In order that the construction and mode of working this valve may be fully understood, I have shown the same in elevation in its proper place on sheets B and C of the drawings hereunto annexed, and in vertical section in the detached Fig. 2 on sheet E. In each

figure, A represents the stand-pipe which conducts the air upward from the main pipes Z. Below the floor B is the valve-box, which consists of a cylindrical chamber with an inner cylinder, C, forming a continuation of the vertical pipe A. The cylinder C is bored truly, and has fitted to it a piston-valve, E, having an elastic metallic packing. Slots are formed in the cylinder C, which allow the air to pass from the pipe A into the annular space D formed between the two cylinders, and from thence into the axis F of the converting-vessel. The piston E, when lowered down, covers the slots and shuts off the communication with the main blast-pipe. It will be observed that the piston-valve has openings, through which the air may pass to its upper side, in order that the pressure of the air may be equalized on both sides of it, and thereby allow the weight G to retain it in place when lowered down. A cam, H, is keyed onto the axis of the vessel, and above it there is a lever, I, jointed at one end, and at the other it passes through a slot in the rod of piston-valve E. A projecting piece from this lever rests on the cam so that the cam may, by means of the inclines formed on its periphery, cause the lever I to rise and fall, and with it the piston-valve, and thus, by the motion of the converting-vessel, the air may be let on or shut off at any point required, and which will depend on the configuration of the cam, as is well understood.

The tuyere box or chamber forming the lower part of the converting-vessel has hitherto been made so as to gain access to each of the tuyeres through one opening, each tuyere communicating with one air-chamber common to all. It has therefore sometimes happened that the failure of one tuyere has allowed the fluid metal to descend into the tuyere-box, and thus for the time prevent all further use with either of the other tuyeres, and thus rendering the completion of the process impossible, as well as rendering each tuyere unfit for further use.

Now, my present improvement in this part of the apparatus consists in forming several small tuyere-boxes, each containing a single tuyere, with any suitable number of openings in it. A single tuyere-box so formed is shown in section at Figs. 8 and 9, sheet E. It is of a cylindrical form, and has a beveled opening, J, at one end, into which the conical end of the tuyere K is fitted. The box is closed by a lid, L, and the tuyere-box is provided with an outer flange, M, by which it is bolted to the lower side of the converting-vessel. Any convenient number of such separate tuyere-boxes may be grouped together and be connected to the blast-pipe by separate branch-pipes communicating with an opening made in the side of the box, as shown at N.

My improvements also consist in forming one tuyere-box with several separate compartments, so that a failure of one of the tuyeres may not prevent the continuation of the process with the other tuyeres, the faulty tuyere being stopped by a plate of iron coated with loam, or it may be removed and the full efficiency of the apparatus insured by the insertion of a fresh tuyere in its place. The tuyeres being made conical and occupying separate compartments will give great facility for their removal and replacement

with new ones, either before the completion of a charge of metal under operation or after it has been converted and run out of the vessel and previous to a repetition of the process. This mode of combining several separate compartments each containing a tuyere admits of the several tuyeres being placed nearer to each other than can conveniently be done when separate tuyere-boxes are used.

The mode of construction which I prefer is represented on sheets A and E of the drawings hereunto annexed, where Fig. 10 is a vertical section through the lower part of the vessel and tuyere-box; Fig. 11, a plan of the under side, and Fig. 12 a section taken through the box on the line G H of Fig. 10.

The tuyere-box Q, as here represented, consists of an iron casting having seven circular chambers, W, formed therein, into each of which the tuyeres R are fitted and made air-tight by a luting of clay smeared upon the lower conical part of the tuyere at the time of fitting it into the box, the conical opening into which it fits having rings or grooves formed around it the better to hold the luting in place. A bar of iron, S, with a screw passing through its center, is fitted across the circular chamber, for the purpose of forcing the tuyere tightly into its seat and retaining it there.

T T are covering-plates, for the purpose of closing the several compartments of the tuyere-box by means of slotted studs having cotters passing through them, as shown. The joints of the covering-plates are rendered tight by a gasket of hemp covered with very soft clay or lime and water in a semi-fluid state. The air is forced into the tuyere-box by the pipe U, and, passing into the closed space between the circular chambers, enters them through lateral openings X, and from thence through the orifices of the tuyeres 1272 into the fluid metal. The tuyere-box is attached to the converting-vessel by bolts, which pass through the flange Q* of the tuyere-box.

It is sometimes found desirable to form ingots or castings of a greater weight than can be produced in a converting-vessel of a convenient size. To effect this object without the necessity of erecting larger vessels I place two or more converting-vessels in such a position with reference to each other and to the crane which supports the casting-ladle that two separate charges of metal may simultaneously be converted, and be afterward poured one quickly after the other into the same casting-ladle, and thereby be made to produce an ingot or casting in one piece equal in weight to the produce of the two vessels, the position of the said vessels with reference to each other being also such as to render it convenient to repair either of them while the other one is in active operation. For this purpose I place the vessels several feet apart and opposite each other, each one having a separate chimney to take off the flame and products of combustion, the chimneys being in a line with the two vessels which are placed between them and at a small distance from the wall of the melting-house, the axes of the vessels being parallel to each other and at right angles to the plane of the said wall. The chimneys are built on open arches, from under which the workman may have ready access to the tuyere-boxes

when the vessels are turned into a horizontal position. The space above the arches may be lined with iron plates, and thus form receptacles for the splashes or slags thrown out during the converting process.

The relative position of the converting-vessels and the construction of the chimneys will be seen by reference to sheets B and C of the annexed drawings.

At Fig. 1 on sheet B I have shown the chimney 8 and vessel 9 in vertical section, and on the opposite side of the drawings I have shown the chimney 10 and the converting-vessel 11 in elevation. The general arrangement of the several parts may also be seen in plan on sheet C, Fig. 1. A portion of the floor of the converting-house is sunk below the general level. The sunk part, which forms the casting-pit, is represented at 12, and the upper or general floor-level at 13. A further portion, 14, is also sunk to an intermediate depth, free access to which is given by the steps 15 and 16. This curved space 14 extends partly around the casting-pit, and is for the purpose of allowing the workmen free access to the molds at the time of casting the ingots, the molds being arranged in a semi-circle in the casting-pit and near to the curved wall which bounds the casting-pit on the side where the sunk space 14 is formed. The chimneys are built on open arches 17, the piers of which are shown in plan at 17 on sheet C. Above the arch an iron plate, 18, forms a sort of shelf, on which the splashes of slag thrown from the vessel are received, there being an arched opening into the chimney at 19 with a projecting hood, 20, the better to collect the flame and heated gases from the vessel and cause them to ascend the chimney, which contracts in width by a series of "sets off" in the brick-work, above which it is square, and passes up through the roof of the building to any convenient height. An iron door, 22, will enable the workman to enter and clean out the chimney, and will also afford access for the purpose of putting fuel into the vessel when it is required to heat the vessel prior to commencing work.

On reference to sheet B, it will be seen that when either of the vessels are being used the splashes thrown out of one will be in an opposite direction to the other vessel, so that the repairs of one vessel or setting or renewal of tuyeres may be going on in one vessel while the other vessel is in operation, or both vessels may be worked at one time and their respective charges of metal be poured into one ladle, and thence transferred to a single mold when large masses are required. In my patent No. 49055 I have described certain advantages due to this arrangement of ladle and ladle-crane. The ladle being held in a fixed position relatively to the crane-arm will not have a swinging or spinning motion, but is at the same time capable of tipping. It will be obvious that these advantages may be realized in an equal or greater degree when a ladle and crane thus arranged are combined with two or more converting-vessels.

The vessel 9 is shown in the position necessary to afford free access to the tuyere-box, the workman standing for that purpose beneath the open arches 17 of the chimney. Metal is supplied to these vessels through openings 23, a gutter being temporarily placed to convey

the fluid iron from the melting-furnaces, which I prefer to place on the opposite side of the wall of the converting-house, and at such a height above the general floor-level as will admit of the metal flowing from the furnaces direct into the mouth of the vessel. The doorway and steps shown at 24 serve to communicate between the converting-house and the furnace-room adjoining.

It will be seen that the converting-vessels are mounted on axes resting at one end on a standard supported by the bed-plates 1 of hydraulic apparatus, and at the opposite ends are supported on standards 25, bolted firmly down to the foundations. The casting-crane occupies a position midway between the two converting-vessels, the center of it being farther from the melting-house wall than the converting-vessels. When the converting-vessel requires to be relined the upper part of the vessel should be removed, and after the old lining of stony matter is broken out of the iron shell the new material is to be rammed in and the two parts again carefully put together, and so as to avoid the displacement of any portion of the new lining, which possesses very little coherence until it has been fired. To effect this separation of the vessel and its after union the vessel should be inverted or turned mouth downward. Below its center and beneath the floor of the casting-pit I fix a small vertical hydraulic cylinder and ram, the upper part of the ram being provided with a forked piece so made as to embrace the movable part of the vessel and retain it in its proper position. By this means one part of the vessel may be lowered down vertically beneath the other portion, which is still retained in position by resting on its axes. After the vessel is relined it may be steadily raised into its former position, and be there united by bolts to the other part. On sheet B the upper part of this small hydraulic ram is shown in vertical section.

1273

26 is the cylinder, which fits accurately to the ram or plunger 27 for a sufficient distance to cause the ram to rise and fall steadily. A hydraulic leather keeps a water-tight joint in the usual manner, and the pipe 28 is connected to a reservoir of water under pressure or to force-pumps, so that by means of a cock the ram may be raised and lowered when required. A forked piece for the upper part of the vessel to rest on, and shown by dots, is made to fit into a socket (shown at 29) in the head of the ram, the forked piece being removed when not required for lowering the top of the vessel.

In the conversion of crude iron into steel or malleable iron by forcing air therein it has been found that some kinds or qualities of iron are converted much more rapidly than others. This is especially the case with some of the purer kinds of charcoal pig-iron. It has also been found that some irons thus rapidly converted acquire a higher temperature if blown into by horizontal tuyeres, because by this means there can, if desired, be employed a larger orifice and less pressure of air than has been generally employed when blowing vertically upward into the metal. This arrangement also enables the air to be blown in at various points, which is advantageous. Now, in order to obtain the high temperature producible under such circumstances and to retain the advantages

derivable from the axial motion of the vessel, I prefer to construct a vessel mounted on trunnions and provided with a line of tuyeres either extending horizontally around, or nearly around, the lower part of the vessel, the part where the tuyeres are situated being of a somewhat less diameter than the cylindrical body of the vessel. I also make the vessel of less height in proportion to its diameter than the movable vessels hitherto constructed, while the back part of it is curved outward, so as to contain the metal when it is turned up and prevent too great a pressure over the orifices of those tuyeres which are situated at or near the back part of the vessel.

The form and construction of this modification of the converting-vessel is represented on sheet A of the drawings hereunto annexed, where Fig. 2 is an elevation; Fig. 3 a vertical section on the line A B of Fig. 4, and Fig. 4 a horizontal cross-section on the line C D of Fig. 3. The position into which the vessel is turned when receiving its charge of melted iron is also shown at Fig. 5 on the same sheet. This form of converting-vessel is, by preference, constructed of plate-iron having a trunnion-band, *f*, passing around its largest circumference and secured by rivets or bolts to the vessel. It has also one solid trunnion and one hollow trunnion for the passage of the blast, as in other converting-vessels now in use.

The upper portion of the vessel *g* is bolted to the trunnion-band, and may be removed when the vessel requires relining; but the lower part, *g**, of the vessel is riveted or otherwise firmly secured to the trunnion-band, and has a channel, *h*, extending around it. This channel is provided with a number of openings both on its internal and external circumference. It is through these openings that the tuyeres *i* are inserted. The outer openings are secured by plates *k*, screwed on over them, the lining of the vessel and the setting of the tuyeres being effected in a similar manner to those now in use. A pipe, *m*, from the hollow trunnion will allow the air to pass down on the outside of the vessel and enter the hollow annular channel *h* and supply the tuyeres, which may have one or any other number of holes in them, as at present practiced. I have before shown how two charges of metal simultaneously converted may be poured into one casting-ladle.

It will be obvious that the converting-vessel may, if desired, be fixed instead of being movable, as I have described it, and still be provided with the line of tuyeres mentioned.

The extra weight of metal to be dealt with in such cases renders some modification of the casting crane and ladle desirable; and, in order that the general construction and mode of operating with this improved form of crane may be fully understood, I have shown the same in elevation on sheet B and in plan on sheet C of the drawings hereunto annexed. Most of this apparatus works in the manner set forth in my letters patent No. —; but for convenience I will here repeat a part of the description of it therein contained.

The great weight of the double charge of metal is also thrown on one arm of the hydraulic crane. I prefer to neutralize by placing on the other arm of the crane a counterbalance-weight, movable on four flanged wheels, which run on the side cheeks of the crane-arm,

the wheels receiving motion by means of a handle and worm-wheel, the latter being fixed on the axle 40 of one of the pairs of wheels 41 and 42, whereby the weight 43 may be moved so as to balance the varying quantity of metal contained in the ladle. The head of the crane, which carries the ladle 44 and counter-weight 43, is suspended on a ball-joint formed on the top of the ram 46, to which ram a spur-wheel, 47, is keyed. A pinion, 48, gearing in this wheel also carries on its axis a beveled wheel, 50, through which motion is communicated from a horizontal shaft, 51, which passes
1274 through bearings in the side cheeks, 52, of the crane-arm, and is provided with handles on each end, by turning which a slow and steady motion of the head of the crane takes place. The casting-ladle 44 is supported on trunnions formed thereon, and rests in bearings formed near the ends of the crane-arm, the axis of the ladle being at right angles to the cheeks 52 of the crane. The motion of the ladle on its trunnions is effected by a worm and wheel, 54, to which motion is communicated by a shaft and handles. This shaft 55 works in bearings formed in the crane-arm, and a pair of beveled wheels, 56, serve to communicate its motion to the worm which moves the ladle. The valve or stopper used for running out the fluid metal is placed on the side of the ladle farthest from the center of the crane, as seen at 57. The desired motion upward and downward of the crane is effected by the admission or discharge of water under pressure to the cylindr 58, by which means the ram or plunger which supports the head of the crane is put in motion and the height of the ladle adjusted to suit the height of the molds. The motion of the ladle on its axis affords facility for the discharge therefrom of fuel put there to dry it, also the slags or other matters left after it has been used. It also allows the ladle to be inverted over a fire when that mode of heating is preferred. The cylinder in which the ram of the crane works I prefer to make in two parts, the lower one being cast with a closed bottom and the upper one open at both ends, and having ribs projecting inward which fit close to the ram, the spaces between these ribs giving ingress and egress to the water by which the ram is put in motion, and thus enabling the water-pipe to be connected to its upper end.

In some cases I form on the exterior of the casting-ladle, and near to or below the bottom of it, a small chamber, bowl, or receptacle lined with loam, and also provided with a valve or stopper with a suitable handle for working the same. This valve is fitted to an orifice or nozzle formed in the lowest part of the receptacle, and is for the purpose of regulating the supply of metal to the molds, the molten metal in the ladle being supplied to this receptacle by a valve or stopper similar to those now in use, so that the receptacle may be kept full up to a certain level during the casting operation, the use of this receptacle being to lessen the pressure of the fluid over the escape-orifice into the mold, and by that means cause the column of fluid to enter the mold with a velocity lessened in proportion, as the head of the metal in the receptacle is less in perpendicular height than the head of metal in the casting-ladle. A ver-

tical section of this form of casting-ladle is shown at Fig. 6 and
plan at Fig. 7, sheet A, of the drawings annexed.

The whole of the vessel may be constructed of plate-iron, and
lined with loam or other suitable slow conductor of heat, the orifi
through which the metal flows being by preference formed in sm
pieces of well-burned fire-clay, retained in their places by the loa
or other lining.

The valve-rod V may be made of iron, and defended with a co
ing of loam, as practiced with the valve-rods generally employed
such casting-ladles.

The different hydraulic apparatus employed in the process
manufacturing malleable iron and steel may be efficiently work
in any well-known manner.

In order that the movement of the converting-vessels and cra
may be under perfect control and that the workman who direc
the process may readily effect all such movements of the apparat
without loss of time, it is preferable that the several valves b
which these movement- are effected, as well as the air-valve
should be arranged near to each other and in such a position th
the workman may observe from that place the operations that a
going on; and in order that the arrangement of these valves ma
be fully understood I have shown the same in elevation at Fig.
in plan at Fig. 5, and in end elevation at Fig. 6 on sheet D of th
drawings annexed, where Fig. 7 is also a plan of the index-plate
the valves and Figs. 8, 9, and 10 details on a larger scale. It
desirable to place these valves near to each other, and for this pu
pose I form a long, rectangular trunk or box, A, into the centr
compartment of which the air from the blast-engine is conducte
by a pipe, B. On the upper side of the box I fix a pair of doubl
beat balance-valves, C, with suitable lever-handles D passing throug
slots E in the table F, before which the workman places himse
These valves admit air in such quantities as are found desirable t
each of the vessels. A pressure-gage may be fitted on the tabl
showing the pressure of the air and indicating to the workman th
effect he is producing by each movement of the air-valves on eac
side of the trunk or box A. The passages G and H are formed, on
to receive water under pressure from the force-pumps by the pip
G* and the second one to receive the waste or back water and re
turn it by the pipe H* to the cistern that supplies the pump
Mounted over these passages and communicating with them are
pair of four-way cocks, I and J, which are turned by spur-gearin
K. Two vertical shafts, L, rising above the table F, are provide
with small fly-wheels M M and handles, so as to allow the work
man to operate readily on the cocks whenever any movement o
the vessel on its axis is to be made. A three-way cock, N, is simi
larly mounted with spur-gearing O and handles, P, for the purpos
of controlling the motions of the hydraulic crane and enabling th
workman to raise the large ladle with facility above the level of th
molds, into which the fluid malleable iron, or steel is to be passed
In operating with these valves the workman stands on the plate Q

which is raised a few feet above the general floor-level of the
1275 building, the table F being at a convenient height, so as to enable him to have full control over the several handles before him.

The lever-handles D are made with an angular projection at their lower ends, which enter slots formed in the spindles of the balance-valves C. This lever-handle is shown more clearly at Fig. 8. The vertical section, Fig. 10, and cross-section, Fig. 9, show the internal form of the valve-box C and the manner in which the valves R balance each other, and thus admit of their easy movements by the lever-handle. Two small cocks, S S, are also mounted on the trunk A, and are made to communicate with the pressure and escape passages G and H. These cocks have a square formed on their keys, in order to move them when required. They are made to communicate with the small hydraulic cylinders employed to raise and lower the upper part of the converting-vessel when a new lining is required.

The blast-pipe T and water-pipes V communicating with the several cocks are carried underground to the different apparatus for which they are required, and thus allow one workman to have the movements of the vessels and crane as well as the supply of air under his control.

Having described the manner in which the several parts of my invention may be carried into practical operation, I desire it to be understood that I do not confine myself to the precise details hereinbefore described; but

What I claim, and desire to secure by letters patent, is—

1. In the manufacture of malleable iron and steel when forcing currents of atmospheric air through the fluid metal, the combined arrangement, substantially as herein described, whereby the steam employed for forcing such air is generated by means of the heat escaping from the reverberatory furnaces that are employed in melting the iron to be so converted.

2. The opening and closing of the passage conducting air into a converting-vessel by means of the rotary motion of such vessel acting through suitable mechanism on a valve situated in said air-passages.

3. In combination with a converting-vessel, several separate tuyere-boxes constructed and operating substantially as described.

4. The combination, with a converting-vessel, of tuyere-boxes with separate compartments, constructed and operating substantially as described.

5. Employing a pair of converting-vessels placed in such a position with reference to each other that the flame and splashes emitted therefrom shall be projected in opposite directions, substantially as and for the purposes described.

6. Employing a pair of converting-vessels, so movable upon their own axes as to be capable of being placed in such relation to each other that the flame and splashes emitted therefrom shall be projected in opposite directions, and as to be also capable of being

placed, when desired, in such positions as to discharge their contents into the same ladle.

7. Combining with two or more converting-vessels a ladle so arranged and operated, either by means of a crane or in any other convenient manner, that the contents of said vessel may be discharged into it and at the same time so that the ladle shall be capable of swinging or turning on its point or points of suspension while being moved, substantially as described.

8. Combining a converting-vessel with a chimney constructed with an open space beneath it, substantially as described, for the purpose of giving access to such converting-vessel.

9. A converting-vessel provided with a line of tuyeres placed through the sides of the vessel, substantially as and for the purposes set forth.

10. The employment of ladles formed with a second chamber or receptacle attached thereto for regulating the supply of metal to the molds, substantially as described.

11. Combining the valves and cocks by which the apparatus is set in operation, so that the workman may conveniently move them from a given place, substantially in the manner described.

HENRY BESSEMER.

Witnesses:
A. L. HOLLEY.
DAN'L LONGSDON.

1278 UNITED STATES PATENT OFFICE.

ANTON LOHAGE, of Unna Westphalia, Prussia.

Improvement in Casting Steel.

Specification forming part of Letters Patent No. 55442, dated June 5, 1866.

To all whom it may concern:

Be it known that I, Anton Lohage, of Unna Westphalia, in the Kingdom of Prussia, have invented improvements in casting steel; and I do hereby declare that the following is a full and exact description of my said invention.

This invention of improvements in casting steel has for its object the better preparation of the melted steel, especially in large masses, before it is poured or allowed to pass into the molds or into ingots.

The invention is applicable to all steel in a molten state, whether uniformly or thoroughly melted or not, and whether melted by the old method in crucibles or otherwise, or produced by the Bessemer or other process, or partly by one process and partly by the other.

For the purpose of the invention I employ a furnace lined with fire-proof blocks made of material of as neutral a character as possible, the blocks being made to fit. The furnace is provided with a movable funnel made of fire proof material, through which funnel the molten metal is introduced into the interior of the furnace, as mentioned in the specification of patents granted to John Henry Johnson, bearing date 31st of December, 1858, No. 3007. The nose of this funnel reaches to the bottom of the bed of the furnace, or nearly so, and is in part cut away on the part farthest away from the fire-place to allow the metal to flow out therefrom upon the bottom of the furnace. The furnace is heated by any well-known method, preferring coal or coal-gas, in combination with a blast, either hot or cold. I designate that point to which it is necessary to heat all steel in order to insure perfect and sound casting as "overmelted" or "superheated."

The molten steal is conveyed through the funnel, which has been previously heated to a red-heat, into the furnace, the temperature of which has been raised to about the melting point of steel, preferring an excess of that heat to prevent any cooling of the mass.

It is important here to remark that I pour slag into the furnace, together with the steel, or previously melt slag in the furnace, in order to form a protecting cover for the molten steel. The molten metal must be well covered with the slag, which may be obtained either from the melting-pots or from the Bessemer process, or from previous meltings. This covering of slag is, as is well known, to prevent the flames or the blast from coming in direct contact with the molten steel, and is essential to the success of the operation. The heat of the furnace is kept up by means of a fan or other blast till the metal is overmelted or superheated and the whole mass of

molten steel has become thoroughly uniform. The metal is then run from the furnace through one or more tap-holes into a receiver or receivers which have been previously heated, (as is well known,) and when the metal is quiescent it is allowed to pass from the receiver into the molds or into ingots. I continue the blast while pouring the molten steel into the furnace, while it is in the furnace, and while allowing it to run into the receiver or receivers, so as to keep it overmelted or superheated, and this I can do without injury to the steel by reason of the molten steel being always covered with slag.

The process above described I call an "intermediate" process, and by it I am enabled to gather together in the same furnace molten steel, whether uniformly or thoroughly melted or not, and whether melted in crucibles or in any other manner, or produced by the Bessemer or other process, or partly by one process and partly by the other, and make the same uniform for one or more castings or for forming ingots of cast-steel, by continuing the melting process till the mass is overmelted or superheated, thus enabling me to make castings of larger size and several castings or ingots of more equal temper than heretofore.

If the weight of molten steel run into the intermediate furnace is sufficient for the casting intended to be made, or if the temper of the steel does not require alteration, then the process need only be continued until it is overmelted or superheated and the mass has become thoroughly uniform.

The usual experience of a steel-melter, which tells him when the steel in crucibles is sufficiently melted for the purpose of casting, will enable him to ascertain when the mass in the intermediate furnace is overmelted or superheated; can also test the heat by inserting a rod of wrought-iron, and the rapidity of the action of the molten steel on the rod will show the practical melter when the mass is ready for pouring. If, however, the steel be insufficient in quantity, I add to the molten mass solid metal, (which I prefer to be previously heated,) either cast or wrought iron, or blister,
1279 puddled, or scrap steel, taking care to maintain the temper of the steel required for the casting.

I alter the temper of the steel in the intermediate furnace and make the steel milder by the addition to the molten mass of wrought-iron or slightly-carbonized iron, which I prefer to be previously heated.

This power of making the temper of the steel in the intermediate furnace milder enables me to melt the steel in the crucibles (when steel melted in that way is used wholly or in part) harder than is required for the casting, which is an advantage, as it quickens the melting and prevents the crucibles from being prematurely destroyed. I also alter the temper of the steel and make the steel in the intermediate furnace harder by adding to the mass of molten metal more highly-carbonized solid metal, which I prefer to be previously heated.

When I add solid—that is, unmolten—metal to the molten mass in the intermediate furnace, (and which I prefer to add gradually,

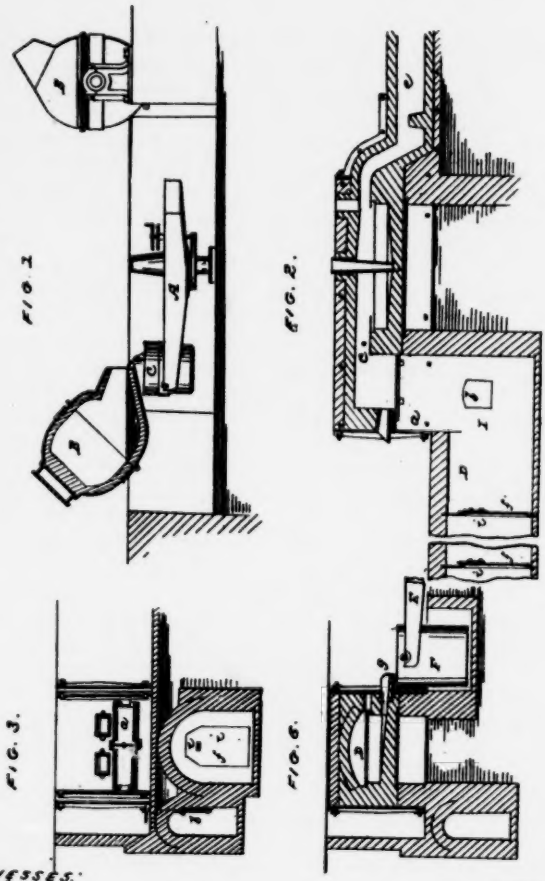
A. LOHAGE.

Casting Steel.

2 Sheets—Sheet 1.

No. 55,442.

Patented June 5, 1866.



WITNESSES:

INVENTOR.

Anton Lohage.

Carnegie Steel Co. v. Cambria Iron Co. } p1276

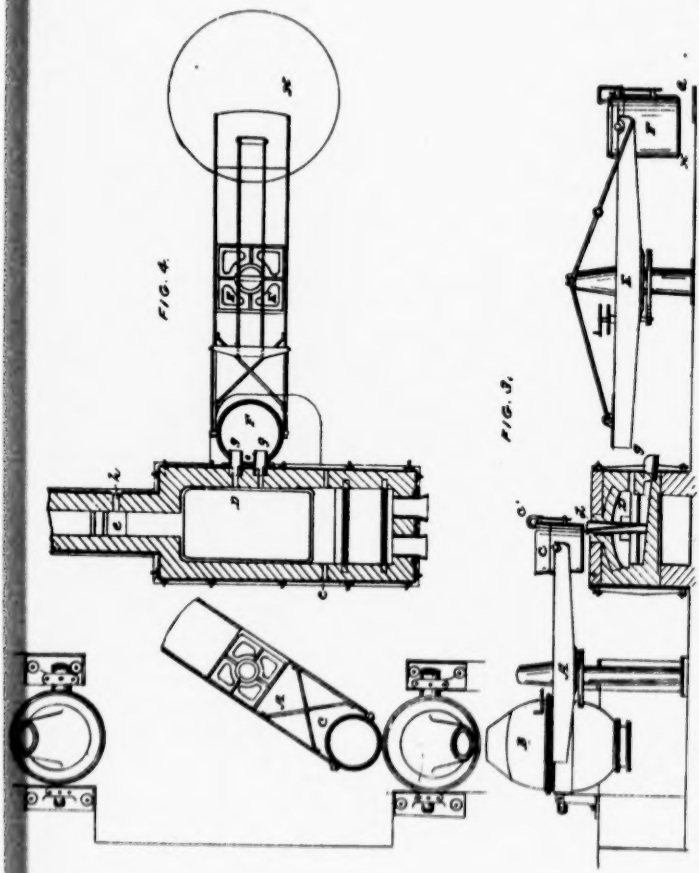
A. LOHAGE.

Casting Steel.

2 Sheets—Sheet 2.

No. 55,442.

Patented June 5, 1866.



WITNESSES:

Carnegie Steel Co.
Cambria Iron Co.

INVENTOR.

Arthur Lohage

and not altogether,) the process will necessarily take a longer time in the intermediate furnace before the steel is overmelted or superheated and the mass has become thoroughly uniform.

When it is desired to add spiegeleisen to the molten metal, as proposed by Mr. Mushet, I prefer to add it to the mass in the intermediate furnace, instead of in the Bessemer converting vessel, as heretofore practiced.

In all cases the process must be continued till the molten steel and the steel or iron added in the intermediate furnace is overmelted or superheated and the mass has become uniform.

The practical experience of steel-melters will enable the operator to determine when the steel is ready for pouring.

When I operate on crucible-melted steel only, I prefer to have the top of the intermediate furnace on a level with the floor of the melting-house. It is not, however, necessary to show this arrangement by drawings.

When I operate on Bessemer steel, either alone or in conjunction with crucible-melted steel, I prefer to arrange the works specially for the purpose. The intermediate process in all cases softens the steel slightly, which allows me, even if I intend no alteration of temper in the intermediate furnace, to melt the steel in the crucible harder in the first instance, which is an advantage.

In the accompanying drawings I have shown the furnace for carrying out my intermediate process, which however may be varied in form, and also the plan I prefer for adapting my invention to steel-works in which the Bessemer process for making steel is employed.

(Here follow diagrams marked pp. 1276 & 1277.)

Figure 1, sheet I, is a sectional elevation of a pair of Bessemer converting-vessels, B B, conveniently arranged for the purposes of my invention. It will be seen that between the two vessels is placed a crane, A, provided with a receiving-vessel, C, into which the Bessemer metal is poured for the purpose of conveying it to the intermediate furnace, which is shown in longitudinal vertical section at Fig. 2. Fig. 3, sheet II, is a transverse vertical section, showing the Bessemer converting-vessel B and the crane A, with the receiving-vessel C, from which the molten metal is being discharged into the intermediate furnace, D. This figure also shows another crane, E, with another and larger receiving-vessel, F, into which the molten steel is run out from the intermediate furnace, D, and is conveyed by the crane E to the mold G to form the casting. The vessels C and F should be heated before being used, as is well understood. Fig. 4 is a plan view of the whole arrangement, the intermediate furnace being shown in section. Fig. 5 is an end view of the furnace; and Fig. 6 is a transverse vertical section of the same, showing the large receiving-vessel F placed ready to receive a charge of molten steel from the furnace D. The intermediate furnace, D, is built so far below the floor of the steel-melting house that the top of the furnace coincides with the floor of the former. The pits H,

to receive the mold G, are placed convenient to the furnace, and suitable foundations for cranes are also placed beneath the level of the floor of the melting-house, as shown in the drawings.

In order to prepare the intermediate furnace for working, I commence by heating the furnace by the fuel in the fire-place, to which end I open the doors *a*, Figs. 2 and 5, andby the natural draft thus obtained I bring up the heat to what I term "almost a white heat." In order to afterward increase the heat I close the doors *a* and open the valve *b*, Figs. 2 and 5, in the blast conduit pipe. The blast is thus driven under the fire-bars by means of a fan or cylinder blast, and causes a very active combustion of the fuel, and the heat in the furnace is thereby much increased. In order to increase the heat still more, and to burn more completely all the gases arising from the fuel, two openings, *c c*, are made above the fire-bridge, as seen in Figs. 2 and 4. A blast fromany convenient source is made to pass through these openings, which are controlled by suitable stop-cocks. When I want to rake the fire to clear the fire-bars or to supply coals to the fire-place, the valve *b* must be closed and the door *a* opened. The molten metal from the receiver C is poured into the intermediate furnace through the funnel *d*, which must be made red-hot in a suitable oven before it is put into its place in the furnace, where it should be placed about fifteen minutes before it is required to be used.

The molten steel is poured into the intermediate furnace through the funnel *d*, and after the necessary quantity of metal is in the furnace the funnel is removed and the opening in the roof is closed by a removable lid or stopper. Before filling the furnace with steel any cinder or other impurities which may have accumulated in it must be removed. Should any slag get into the exit-flue *e* of the furnace it is removed through the opening *h*. When the
1280 steel is ready for casting, the furnace is tapped at *g g*, and I prefer to provide two or more tap-holes, (two are shown in the drawings,) so that if it should be found desirable not to run off the whole charge of molten metal at one operation the tap hole or holes that has or have been used may be plugged up temporarily with fire-clay, and as a tap-hole that has been used cannot readily be reopened in the same place, another tap-hole or other tap-holes may be employed for running out the remainder of the charge. In order to operate upon steel melted in the ordinary crucibles or other melting-furnaces, I simply pour the contents of each crucible through the funnel *d* into the intermediate furnace, or I gather the contents of several crucibles in a receiver previously heated, and then empty that receiver into the intermediate furnace.

After the Bessemer process has been completed in the converting-vessels I empty the contents of the converter into the receiver C, held by the crane A, as shown in Fig. 1. The crane is then raised by means of hydraulic power, as is well known, and the receiver C is brought round over the funnel *d* of the intermediate furnace. The plug C′ of the receiver C is then drawn up, and the receiver empties itself into the furnace, as shown at Fig. 3. After the steel has been subjected to the required degree of heat in the intermediate

furnace until it is overmelted or superheated it is allowed to flow through the tap-holes *g* into the large receiver F, which is held by the crane E. When this receiver is brought over the mold G, placed in the pit H, Fig. 3, the steel is allowed to flow into the mold, as already explained. When it is desired to add to the steel coming from the Bessemer converting-vessels steel melted in ordinary crucibles, either for the purpose of improving the quality or increasing the quantity of the mass, the crucible-melted steel may be poured by single crucibles or from a receiver into the intermediate furnace through the funnel *d*, either before or after the Bessemer steel has been poured into the intermediate furnace.

I can successively pour into my intermediate furnace the contents of two to four, or even more, of the Bessemer converting-vessels, according to the capacity of the furnace and the construction of the steel-works. The molten steel may remain half an hour or longer in the intermediate furnace, and in so long a time it is practicable to make a second conversion in the Bessemer converting-vessels, and this extra quantity can be added to the first in the furnace.

If it be desired to obtain access to the under side of the fire-bars while the furnace is in operation, this must be done from the ash-pit I in the air-channel, to which there are two doors, *f* and *f'*, fitted air-tight, as shown in Fig. 2. The fireman enters through the door *f*, and then closes the same and opens a slide or valve, *i'*, of the second door, *f'*, in order to counterbalance or equalize the pressure of air, after which the door *f'* may be opened. On returning, the fireman closes the door *f'* and opens the slide *i* of the door *f*. The compressed air in the space between the two doors will then escape, and the door *f* may be opened.

I would have it understood that I do not claim the particular furnace and accessories to the same hereinbefore described and shown in the drawings; nor do I claim the special arrangement of the works hereinbefore described and shown in the drawings; but

What I do claim is as follows, that is to say—

1. The process hereinbefore described and called an "intermediate" process, whereby I continue the melting process till the mass is overmelted or superheated, made uniform, and ready for casting.

2. The modes hereinbefore described of altering the temper of the molten steel in the intermediate process.

In witness whereof I, the said Anton Lohage, have hereunto set my hand and seal this 11th day of August, A. D. 1865.

ANTON LOHAGE. [L. S.]

Witnesses:

J. M. HEIMANN.

CASPER BUCKNER.

1282 UNITED STATES PATENT OFFICE.

SAMUEL DANKS, of Cincinnati, Ohio.

Improvement in Rotary Puddling-furnaces.

Specification forming part of Letters Patent No. 96206, dated October 26, 1869.

To all whom it may concern:

Be it known that I, Samuel Danks, of Cincinnati, in the county of Hamilton and State of Ohio, have invented certain improvements in rotary puddling-furnaces, of which the following is a specification:

My invention consists in the construction and arrangement of series of pipes for the conveyance of water, steam, air, or other suitable cooling substance close to the passages to and from the rotary refining-chamber, and projecting corners and surfaces of puddling-furnaces, and to a water, steam, or air casing surrounding the refining-chamber, for the purpose of reducing the temperature of those parts of the furnace most exposed to intense heat, and also to annular metallic facings attached to the refining-chamber for its protection from excessive heat.

(Here follows diagram marked p. 1281.)

Figure 1 is a longitudinal section of a rotary puddling-furnace having my improvements connected therewith. Fig. 2 is a one-half section and one-half elevation of the fire-bridge, the annular water-collar, and the steam, water, or air casing as seen from the grate. Fig. 3 is a sectional elevation of the shiftable piece K, the section being taken through the annular pipe *l*.

A represents the rotary refining-chamber of the puddling-furnace. It consists of a cylinder constructed of suitable refractory metal. Its ends are of the form of truncated cones. B B are rollers, arranged beneath the chamber, which they support while permitting its free rotation, accomplished by means of gearing. The bridge C has incased within it a coil of pipes, D, for the conveyance of water, steam, air, or other cooling substance. The first return of the coil of pipes D is carried through the arch over the passage from the grate to the refining-chamber, as shown at J in Fig. 1. This pipe is connected with the spiral pipe F, incased in the annular water, steam, or air collar G, which is secured to the bridge end of the grate *a*, or about the hot-air passage of which the bridge C forms the lower edge or face. The conically concave face of the annular water, steam, or air collar is of a form adapting it to fit closely the surface of the end of the refining-chamber. A discharge-pipe, H, is connected with the last return of the spiral pipe F in the annular collar G, and terminates at an opening in or near the top of the water, steam, or air casing I, which is constructed of thin metal

S. Danks,

Rotary Puddling Furnace.

No. 96,206. Patented Oct. 26. 1869.

Fig. 1.

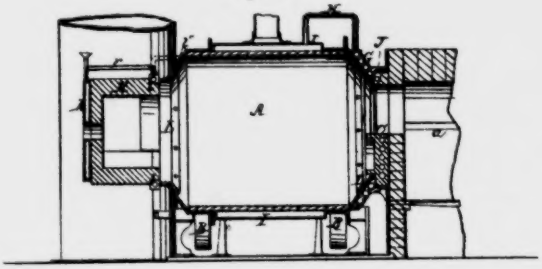


Fig. 3

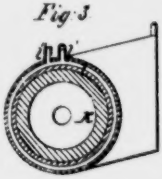
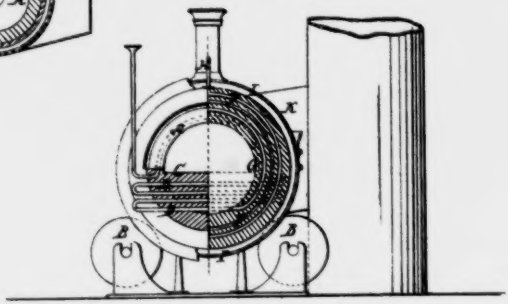


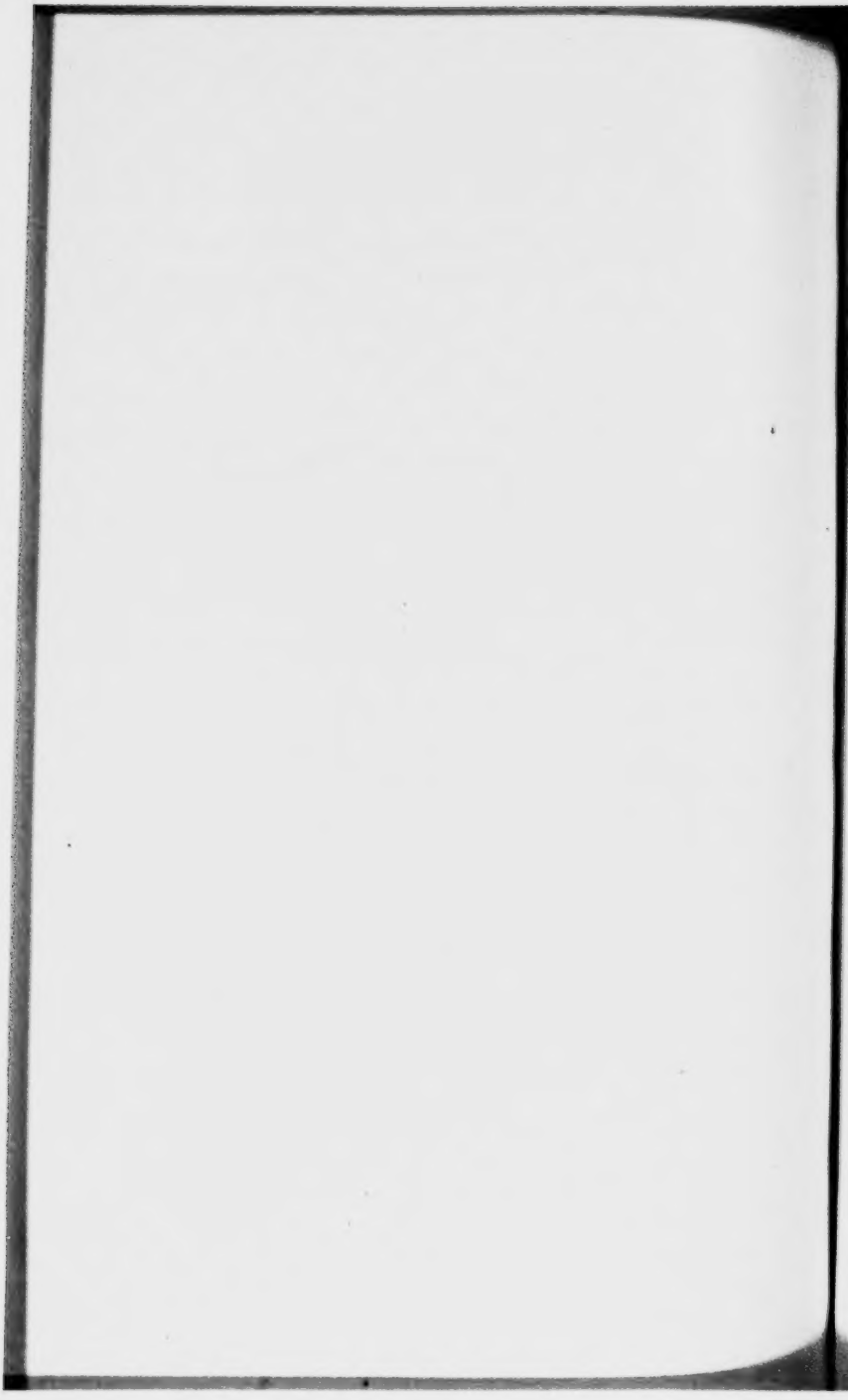
Fig. 2.



Witnesses,
Saml. E. Crumpton
C. L. Fisher

Carnegie Steel Co. } p. 1781
v.
Cambria Iron Co. }

Inventor,
Saml. Danks



having its edges turned in toward the refining-chamber, which it entirely surrounds without being in immediate contact with it.

The mouth of the shiftable piece K, which is in immediate contact with the end of the refining-chamber A farthest removed from the grate, is constructed with an annular pipe, *l*, in the edge thereof, the cooling substance being supplied to it through the feed-pipe *l'*. The inner conical faces of the ends of the rotary refining-chamber A are covered with the annular metal facings L, secured in place by bolts or screws. The outside face of the shiftable piece K is protected from the heat by the steam, water, or air chamber *k*. The edges and faces of the opening from the grate to the rotary refining-chamber over the bridge C, and also the ends of the chamber A and movable section of the smoke-flue, are the parts of the puddling-furnace subjected to the most intense heat, and, consequently, are quickly destroyed.

To prevent the rapid destruction of the exposed parts of the furnace, I have into close proximity with them a series of pipes or confined channels for the conveyance of water, steam, air, or other cooling substance, which flows freely, or may be forced to circulate, through said ducts, that a low temperature may be insured. The current of cooling substance, having passed through the coil in the bridge C, is conveyed by the pipe J over the opening from the grate *a* to the chamber A, into the spiral pipe F in the annular collar G, reducing the temperature of the parts by and through which it passes, and is emptied from the discharge-pipe H upon the top of the rotary refining-chamber A, over the surface of which it spreads, diminishing its temperature. Finally, the steam or gases evolved from the cooling substance in its passage through the pipes escapes under the edges of the casing I, and the fluid part, sinking to the lowest part of the casing, overflows the same edges and escapes into a suitable receptacle.

A cooling substance, such as water, steam, or air, is introduced into the chamber *k*, which is constructed upon the outer face 1283 of the shiftable piece K farthest removed from the grate; thence it is conducted by the pipe *l'* into the annular pipe or chamber *l*, located in one edge of the shiftable piece K, and in contact with the metallic ring L, or, in the absence thereof, with the edge of the refining-chamber A. The cooling substance is carried off, after its passage through the ring *l*, by the waste-pipe *l''*, and discharged into the water, steam, or air chamber between the casing I and the rotary refining-chamber A.

The facings L are attached, in a secure manner, either to the interior conical ends of the refining-chamber A, or to the exterior thereof, by bolts or screws. The facings may, for convenience in handling, be constructed in sections. They serve as an additional protection to the ends of the refining-chamber A.

Each end of the rotary refining-chamber A may be protected, by an annular collar, G, from the action of the heat.

I claim as my invention—

1. The annular water, steam, or air collar G, constructed substantially as herein shown and described, for the purpose of preserv-

ing a low temperature of one or each of the ends of the rotary refining-chamber of puddling-furnaces with which the collar is in contact.

2. The water, steam, or air pipe J, located in the arch of the passage from the grate *a* to the refining-chamber A, substantially as and for the purpose set forth.

3. The water, steam, or air casing I, constructed substantially in the manner and for the purpose herein shown and described.

4. The annular water, steam, or air pipe *l*, located in the edge of the shiftable piece K, which is in immediate contact with the mouth of the refining-chamber when a heat is on, as and for the purpose specified.

5. The water, steam, or air chamber *k*, located upon the outside face of the shiftable piece K, as and for the purpose herein set forth.

6. The annular metallic facings L, secured to the conical ends of the rotary refining-chamber A, substantially in the manner and for the purpose specified.

SAMUEL DANKS.

Witnesses:
SAMUEL E. CRAWFORD.
C. L. FISHER.

1284 UNITED STATES PATENT OFFICE.

ZOHETH S. DURFEE, of New York, N. Y.

Improvement in Methods of Refining Cast Iron and Making Castings.

Specification forming part of Letters Patent No. 118,597, dated August 29, 1871.

To all whom it may concern :

Be it known that I, Zoheth S. Durfee, of New York city, county and State of New York, have invented certain improvements in making castings of iron taken from the smelting-furnace in which it has been made, of which the following is a specification :

Various attempts have been made from time to time to make castings from iron taken directly from smelting or blast-furnaces, but nearly or quite all such operations have been abandoned, because the crude-iron, run directly from the smelting-furnace or from ladles into which it had just been tapped into molds, was found to be too impure and too irregular in character to be relied upon for many of the castings desired.

Now, in order to obviate these disadvantages, and to be enabled to suitably refine the iron tapped out of the smelting-furnace and then cast it into any desired form without suffering it to cool and then remelting it, and also to be able to make conveniently mixtures of other irons with such iron as may be tapped from any smelting-furnace whose product it may be desired to cast without allowing it to cool and then remelting it, I proceed as follows :

I place at any convenient point near the blast-furnace, or within such distance that the crude metal tapped out from the blast-furnace can be carried thereto without losing its fluidity, a reverberatory or other suitable furnace, preferably a gas-furnace, such as the Siemens regenerative gas-furnace, or any similar furnace in which a high heat may be maintained at small cost of fuel, and in which the waste gases of the blast-furnace can be used as fuel in whole or in part, and I pour or run the metal tapped out from the blast-furnace therein.

A very desirable arrangement in connection with such a furnace is described in the specification of a patent sent by me to the Patent Office on the 14th February of this year, as such an apparatus will enable the purification of the metal treated to be easily effected by letting suitable fluxes pass with the metal into the furnace.

When the metal has been poured into the gas-furnace it can be treated in any desired way to refine it, and any metals or alloys of metal can be added at will. The iron in the gas-furnace can thus be kept at any given standard, and part of it tapped out from time to time, as may be required for making castings of any desired quality, and it will be seen that this plan offers great advantages for the manufacture of high grades of castings, such as car-wheels,

malleable castings, &c., as the heat of the gas-furnace can be so far raised as to melt or keep melted the most decarbonized iron.

The gas-furnace may be of any desired capacity, or two or more such furnaces may be used together in making large castings.

In cases where transportation of castings from blast-furnaces to market would be inconvenient or too expensive I obtain some of the advantages of the foregoing process as follows: I combine with one or more reverberatory or gas-furnaces one or more cupola-furnaces, so arranged that the metal melted in the cupolas can be tapped and run into the other furnaces and from the latter into molds or into ladles for being poured into molds. In such cases I use the cupola-furnaces for melting pig-iron, and I prefer to melt therein the most inferior metal to be used, and also all metal the character whereof is not definitely known. The iron so melted will then be tapped into the gas or other furnaces and samples taken therefrom and tested, and thereupon it can be treated in any way to give it the desired qualities for any kind of casting.

It will be understood that the character of the iron in the gas-furnaces can be varied from time to time or kept continuously at one standard; and not only by this means may any desired uniformity or variety in the quality of the castings produced be attainable, but greater economy in cost; because by this plan cheaper mixtures of pig-iron can be made for any given purpose than can be made in cupolas, and such mixtures can be more quickly and cheaply made than they can be by the use of the gas or reverberatory furnaces alone.

I am aware that it is not new to run or pour crude-iron from blast-furnaces into reverberatory furnaces for the purpose of puddling or refining it for being puddled or in otherwise treated for the manufacture of malleable iron and steel, and I make no claim thereto; but I have never known, heard, or in anywise ascertained that the plan herein proposed for cheapening the production and im-
1285 proving and regulating the quality of castings has ever before been proposed or practiced.

What I claim as my invention is—

1. The continuous process, substantially as herein described, of treating iron taken directly from blast-furnaces and making castings therefrom.

2. The herein-described modes of treating iron for the manufacture of castings by first melting it in ordinary cupola-furnaces, and then, previously to founding it, tapping it into reverberatory furnaces and refining it or in otherwise modifying its character.

3. Combining reverberatory or gas-melting furnaces with blast-furnaces, substantially as and for the purposes specified.

4. Combining reverberatory or gas-melting furnaces and cupola-melting furnaces, substantially as and for the purposes specified.

ZOHETH S. DURFEE.

Witnesses:
CHS. H. LADDEN.
EMIL HEUSNER.

J. Y. Smith.

2 Sheets—Sheet 1.

Metallurgic Furnace.

No. 120,005. Fig. 1. Patented Oct. 17, 1871.

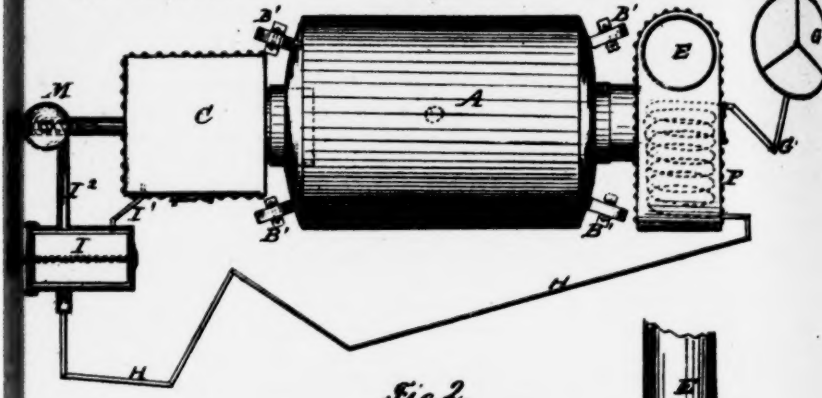


Fig. 2.

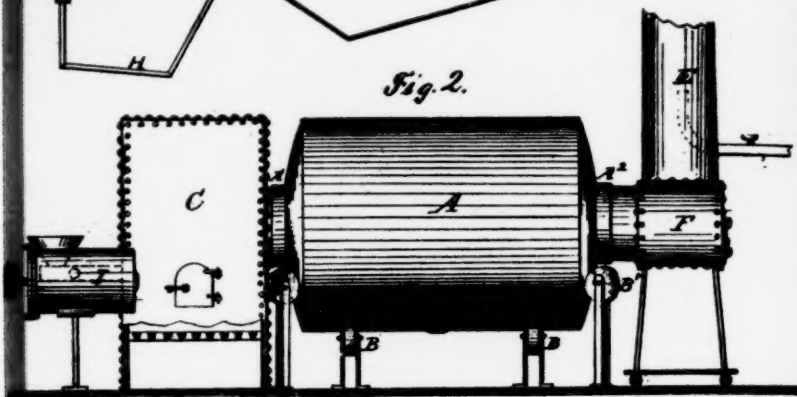


Fig. 5

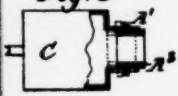


Fig. 4

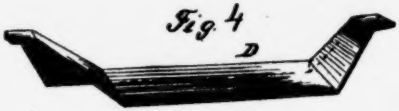
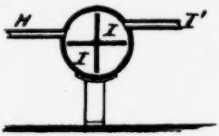


Fig. 3



Witnesses.
C. F. Clausen
A. Ruppert

Carnegie Steel Co.
Cambria Iron Co. } b. 1786

J. Y. Smith
Inventor.
D. P. Holloway
Atty

John Y Smith.

2 Sheets--Sheet 2.

Metallurgic Furnace.

No. 120,005.

Patented Oct. 17, 1871.

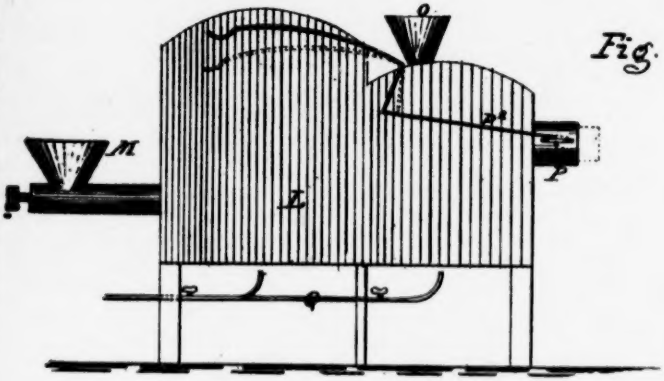


Fig. 6

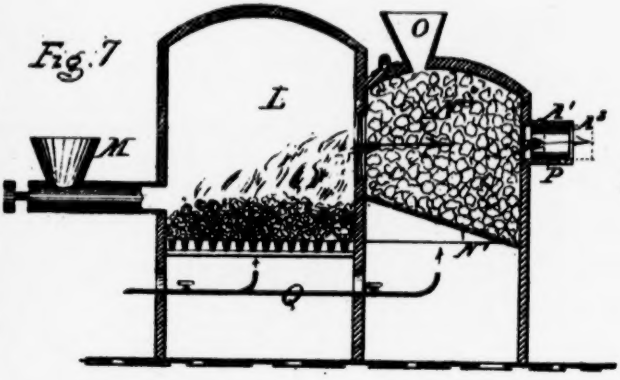


Fig. 7

Fig. 8

Attest

C. F. Clausen

A. Ruppert

Inventor

Carnegie Steel Co.
Camden Works. } p. 1287.

1288 UNITED STATES PATENT OFFICE.

JOHN Y. SMITH, of Pittsburg, Pennsylvania.

Improvement in Metallurgic Furnaces.

Specification forming part of Letters Patent No. 120,005, dated October 17, 1871; antedated October 3, 1871.

To all whom it may concern:

Be it known that I, John Y. Smith, of Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful improvement in revolving puddling-furnaces; and I do hereby declare that the following is a full, clear, and exact description of the same, reference being had to the annexed drawing making part of this specification, in which—

(Here follow diagrams marked pp. 1286 & 1287.)

Figure 1 is a plan view. Fig. 2 is a side elevation; Fig. 3, a section of the fan; Fig. 4, a perspective view of a part. Fig. 5 is a plan and section of the furnace and adjustable throat.

In all the figures the same letters are employed in the designation of identical parts.

My improvements relate to a puddling-furnace of that class in which the furnace is made to revolve; and my invention consists in a new mode of putting a lining into such furnaces and in certain details of construction to be hereinafter set forth.

I have also shown in Figs. 6, 7, and 8 a furnace primarily adapted to this class of puddling-furnace, but also susceptible to application in connection with other kinds of furnaces. In this part of my case my invention consists in placing between the combustion-chamber and the puddling furnace a chamber filled with incandescent coke or anthracite coal or other similar pure carbonaceous substance, through the interstices between which gases evolved in the combustion-chamber are caused to pass, and a perfect combustion thereof is thereby effected.

In the annexed drawing, I have shown at A a revolving puddling-furnace, made in the ordinary manner of staves of iron and lined internally with a refractory lining, to be hereinafter more fully described. This furnace revolves upon the friction-wheels B, being driven in the usual manner. The heads of the furnace are made slightly conical, and other wheels, B′, are so placed and supported that they shall hold the furnace against that tendency to longitudinal movement which I have found, in practice, to be one of the difficulties attending the use of furnaces of this class. The combustion-chamber is indicated at C. It may be made so that it may be wheeled to one side to give access to the interior of the puddling-furnace. I prefer to use as a lining for my furnace pulverized silex, obtained readily by grinding quartz-rock. This is mixed

with a small quantity of salt or lead, or both, and slightly moistened with water. This I put into the furnace in the following manner: Flanged formers D, Fig. 4, are formed to fit the inside of the furnace, extending from end to end, the narrow flange indicated by dotted lines bearing against the case of the furnace and leaving a space between such shell and the inner plate *d*. One of these formers being placed in the furnace, the space between the shell and the plate *d* is packed with the prepared silex, so as to form a lining between the shell and said plate, extending into the throats A^1 A^2 of the furnace. Another former, D, is then introduced, and in like manner packed with the silex, and so on until the entire surface of the furnace is lined. A slow fire is then built and the furnace revolved, and as the silex is dried the intensity of the fire is increased until the silex is fused into a homogeneous mass, forming a perfect lining in one homogeneous tubular mass for the entire furnace. The formers may be removed during this operation as soon as the lining is capable of sustaining itself; or, being made of cast-iron, may be allowed to remain in the furnace until the intensity of the heat melts them. The lining, in hardening, will expand so as to fill the spaces left on the removal of the formers, and a perfect and entire lining of silex be left within the shell of the furnace capable of resisting any heat afterward required in the furnace. The up-take E opens out of a chamber, F, containing a coil for heating the air-blast. The chamber F may be mounted on wheels so that the end of the puddling-furnace may be opened to permit the contents of the furnace to be taken out. In this case the fan-case G must be connected with the hot-air coils by a jointed pipe, G', and the blast-pipe H must also be in like manner jointed so as to permit the chamber F to be moved without disconnecting the pipes. One difficulty in operating this class of furnaces has been to maintain the connection between the movable parts of the furnace and the revolving furnace. This I obviate in the following manner: Inside the throats I place rings made of silex in the manner set forth. These rings are placed inside the throats, so as to fit neatly, but to allow the longitudinal adjustment of the rings. The rings may be operated by means of the weighted lever shown in
1289 Fig. 6, attached to the ring A^3. The rings will be pressed together, but as they wear the lever will keep the ends in contact; and when a ring is worn out it may be readily replaced by a new one.

I propose to use in connection with the furnace finely-pulverized fuel; and to feed this to the combustion-chamber I desire to employ the force of the blast. To this end I use a case, I, containing a fan which is driven by the blast passing through the case. The blast is then partly conducted directly into the combustion-chamber through the pipe I^1, and partly through the pipe I^2 into the fuel-feeder, to carry with it the finely-pulverized fuel into the combustion-chamber. On the end of the fan-shaft which passes through the end of the case I is a pulley connected with the pulley on the end of the spiral feeder placed in the fuel-injector K, so that the revolution of the fan-wheel gives motion to the spiral feeder.

Instead of the ordinary furnace, I prefer to use one made on the principle of that shown in Figs. 6 and 7. The combustion-chamber L may be constructed with the ordinary grate-bars for burning solid fuel, or with the fine-fuel injector M, or both. Between the combustion-chamber and the revolving or other furnace I place another chamber, N, to be filled with lumps of a pure carbonaceous fuel, such as coke or anthracite coal, the lumps being of such size as to permit the draught to be forced through their interstices. This may be effected by means of the pressure-blast or by the aid of an exhaust-pipe in the up-take, through which a jet of steam is forced into the up-take, or by both combined. These lumps may be fed into the chamber N through the hopper O. This chamber should also be constructed with grate-bars N′, to permit the ashes and clinkers or other solid product of combustion to be drawn off. The pipe Q is intended to discharge a blast of air under the grates, as shown. The gases of combustion, or the carbonized air, in passing through the chamber N and between the incandescent lumps therein, will be heated to the highest possible degree and a perfect combustion effected. By this means I am able to produce a pure reducing flame in the furnace.

I am aware that a furnace is shown in Tooth's English patent No. 277 of 1860, having a chamber placed between the fire-box and the puddling-furnace to be filled with gas-yielding coal, to be distilled by the action of the heat passed through the mass; but it is no part of my purpose to make gas in this chamber; on the contrary, it is indispensible that the coal used should be as nearly as possible pure carbon, the best material being a pure anthracite or coke or charcoal, for, if the material used will yield a gas under the action of the heat other than a pure carbonic acid or oxide, it will not answer the purpose in view in this invention, which is the purification and heating of the gases evolved in the fire-box.

It is obvious that this form of heating-furnaces may be used with other kinds of furnaces, and also that other furnaces for generating heat may be used in combination with a furnace such as that shown. I do not, therefore, limit my claim to the use of the two in combination.

I am aware that revolving puddling-furnaces are in common use; and also that the use of pulverulent fuel is common; and also that such fuel has been injected over the surface of fires of solid fuel or mingled with the gaseous products thereof; and also that it has been proposed to drive jets of pulverulent fuel against the surface of lumps of refractory substances piled in the combustion-chamber and maintained in an incandescent state to assist in burning the particles of fuel. None of these things are, therefore, claimed unless such lumps of refractory substances are used in a chamber such as N.

What I claim as my invention, and desire to secure by letters patent, is—

1. A revolving furnace, A, the inclined heads of which are supported against friction-wheels B′, substantially as and for the purpose set forth.

2. A revolving furnace, A, when lined on the interior by a solid tube of homogeneous material formed by the action of heat, substantially as set forth.

3. In combination with a revolving furnace, adjustable rings of refractory material for forming the joints between the necks of the furnace and the parts connected therewith.

4. The formers D, when used in combination with the shell of the furnace to form the lining thereof, substantially in the manner set forth.

5. In combination with the blast-pipe and spiral fuel-feeder M, a fan and case, I, when respectively so constructed and connected that the blast shall operate the feeder, substantially in the manner set forth.

6. In combination with the combustion-chamber L, a chamber, N, filled with incandescent lumps of a pure carbonaceous substance, such as coke, or anthracite coal, through which chamber the gaseous products of combustion are forced, substantially as set forth.

7. In combination with an apparatus for feeding finely-pulverized fuel to be burned while floating in the air, a chamber, N, filled with incandescent lumps of such carbonaceous substances as aforesaid, through which the carbonized air is forced, substantially as set forth.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

JOHN Y. SMITH.

Witnesses:
B. EDW. J. EILS.
A. RUPPERT.

1290 UNITED STATES PATENT OFFICE.

ZOHETH S. DURFEE, of New York, N. Y.

Improvement in the Manufacture of Iron and Steel.

Specification forming part of Letters Patent No. 122,312, dated January 2, 1872; antedated December 16, 1871.

I, Zoheth S. Durfee, of the city, county, and State of New York, have invented certain improvements in the pneumatic or Bessemer process for making iron and steel, and in the combination of the furnaces and converters connected therewith, of which the following is a specification:

In the manufacture of steel by the pneumatic or Bessemer process a great saving of fuel and iron, of wear and tear of furnaces, and of labor would be effected were it possible to make uniformly good products of the desired temper by converting the crude iron immediately it is tapped from the blast-furnace in which it is made. This plan has been and may still be practiced to a considerable extent; but it has been found that by reason of the irregular working of blast-furnaces, and the consequent varying character and quality of the crude iron produced, it was always very difficult and in most cases impossible to secure such uniformity in the converted metal as was essential to success in the business. Hence, at several establishments where the plan of taking the fluid iron as it was tapped from the blast-furnace and pouring it at once into the converter has been practiced, it has been abandoned, the proprietors preferring to incur the expense of handling and remelting the crude iron after it had been cast into pigs in order thus to secure the advantage of carefully selecting and mixing the materials for each charge to be converted. Now, in order to secure the greater portion of the saving due to taking the iron from the blast-furnace to the converter without its being allowed to cool and solidify, and at the same time to obviate the disadvantages resulting from the variations in the character and quality of the blast-furnace product, and in order also to be able to mix irons to any desired extent, I propose to place at any suitable points near the converting vessels—and by preference at such height as will permit the metal to be run into the converters from them without previously hoisting the ladles, into which the metal may first be tapped—reverberatory-furnaces, by preference gas furnaces, into which furnaces the crude iron as it is brought from the blast-furnaces may be poured, and wherein it may be mixed with other irons and be so treated as to insure the metal from time to time tapped out for conversion being as nearly as practicable of a uniform character. So many and so large furnaces may be used as the work in progress may demand; but in many cases one furnace of about double the capacity of the converter in use will be sufficient, as the necessary correction of the character of the crude iron can be very quickly made. Gas-furnaces offer especial advan-

tages for this purpose, as they use much less fuel in maintaining a given temperature than do the ordinary reverberatory-furnaces, and can readily produce the highest heat required. After the iron from the blast-furnace has been poured into the reverberatory-furnace pig-iron of different qualities, or any metals or metalloids which it may be desired to mix therewith, may be introduced, and so also, may any fluxes which may be useful. Some qualities or grades of crude iron cannot advantageously be used in the Bessemer process, because they do not contain sufficient quantities of heat-giving elements, such as carbon and silicum, and consequently work cold, and the steel produced from them chills so quickly that it cannot be tapped from the ladles. Now, with the use of gas-furnaces as herein proposed, such metals can be so highly heated before they shall be poured into the converter that the lack of heat-giving elements will be compensated, and as iron lacking such elements—chiefly the higher numbers of pig-iron—is sold at lower prices than those irons which contain them, reverberatory-furnaces may also, in many cases, be advantageously used when iron is to be remelted for conversion; and when in such cases it may be cheapest to use cupola-furnaces for melting the pigs I would place a reverberatory-furnace at some convenient point between the cupola-furnaces and the converters, and tap the iron from the cupolas into the reverberatory-furnaces, and from thence, after first giving it the desired character and temperature, into the converter. It will be understood that these reverberatory-furnaces will give all needed opportunity for testing the irons under treatment, and also superior facilities for remelting any ingots and scraps which require to be reconverted; and when reverberatory furnaces are used alone or in combination with
1291 cupola-furnaces arrangements may be made for hoisting any metal, which, in consequence of derangements of the converters or any of the connected apparatus, may require to be poured from the converters before it is completely converted, and pouring it into the reverberatory-furnaces so that it may be prepared for being returned to the same converter from whence it was taken, if it shall have been repaired, or to some other which may be in order. In case gas-furnaces are thus used in connection with cupola-furnaces, the latter may be so constructed as that the waste gases therefrom may be taken off for working the reverberatory gas-furnaces.

What I claim as my invention is—

1. Combining converting-vessels with reverberatory-furnaces and blast or smelting furnaces in such wise as that the crude iron can be tapped and run or carried, raised, and poured from the blast-furnaces into the reverberatory-furnaces, and then, after being treated as may be desired, be tapped out and be run into converters, substantially as and for the purposes described and specified.

2. Combining converting-vessels with reverberatory-furnaces and cupola-furnaces, in such wise as that the metal melted in the cupola-furnaces can be run from thence into the reverberatory-furnaces, and from the latter to the converters, substantially as and for the purposes described and specified.

3. I claim the herein described modes of producing uniformity in

the character of the iron to be converted by the pneumatic or Bessemer process.

4. I claim the plan herein-described of increasing the heat of metals to be converted by the pneumatic or Bessemer process.

5. I claim so combining the apparatus used in the conversion of crude iron by the pneumatic or Bessemer process that the metal under treatment in the converters can be poured out and transferred to a reverberatory-furnace, and then tapped back into the converters, substantially for the purposes specified.

ZOHETH S. DURFEE.

Witnesses:
WM. H. SEYMOUR.
JOHN L. SWIFT.

1294 UNITED STATES PATENT OFFICE.

WILLIAM SELLERS, of Philadelphia, Pennsylvania.

Improvement in Apparatus for Puddling Iron.

Specification forming part of Letters Patent No. 124,224, dated March 5, 1872.

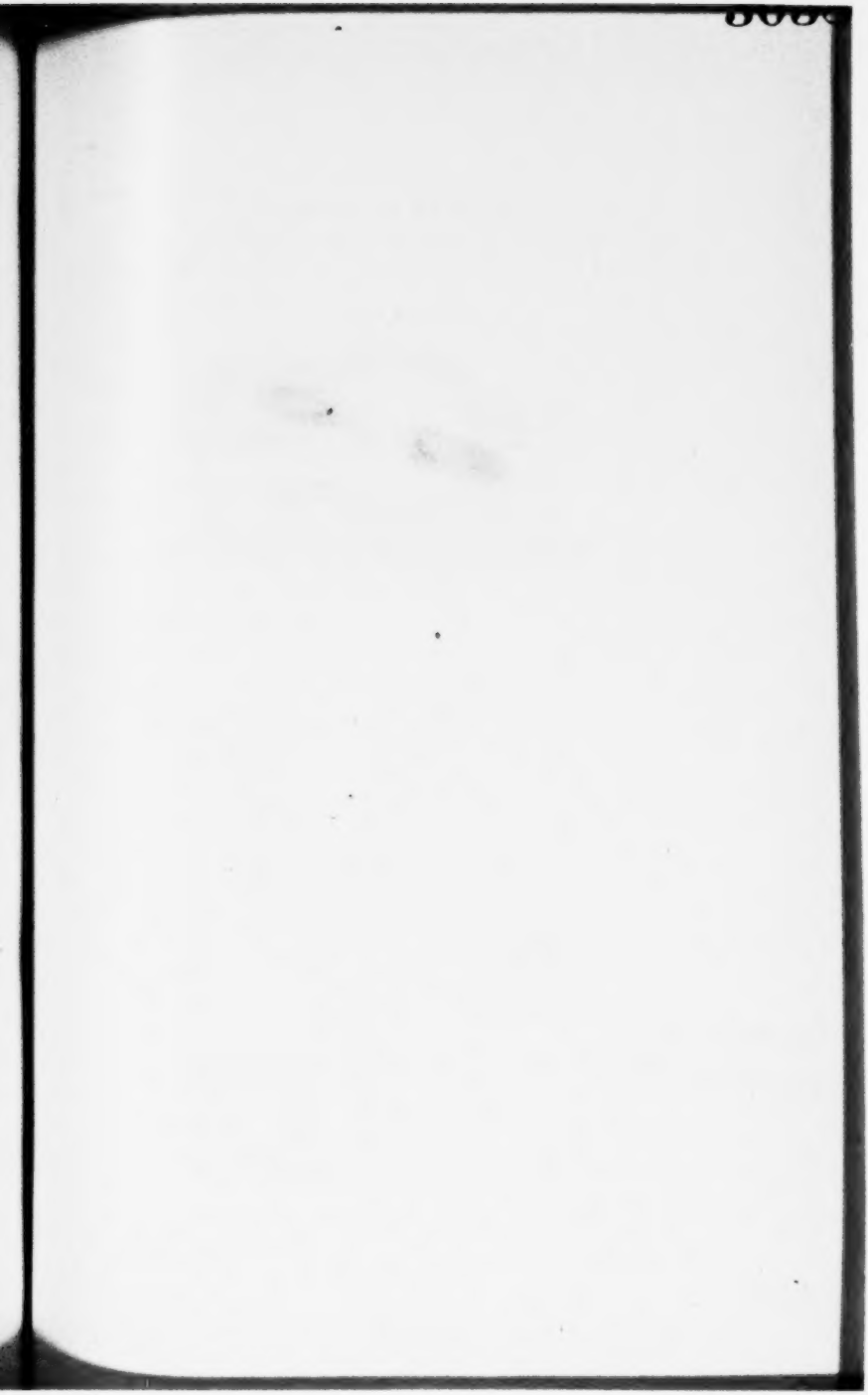
To all whom it may concern:

Be it known that I, William Sellers, of the city and county of Philadelphia, in the State of Pennsylvania, have invented certain new and useful improvements in the mechanical puddling of iron, the following being a specification of my said improvements.

My improvements relate to that class of puddling-machines in which the process is effected by revolving the chamber or vessel which contains the metal to be operated upon in such a manner as to present a constantly-changing surface of the contained metal to the action of flame.

Heretofore, in all machines in which puddling has been thus effected, the flame has been passed into, through, and out of the chamber or vessel in the direction of the axis of the vessel, the respective openings for the entrance and the exit of the flame being opposite each other. In my improved machine, on the contrary, the flame passes into the puddling-chamber or vessel in the direction of its axis; but, instead of passing through and out of the chamber, as above-described, it sweeps over the whole of its interior surface, and returns to and passes out of the opening in the chamber at which it entered, thus operating upon the contained metal more economically and more effectually.

Again, in order to charge or to discharge revolving puddling-chambers or vessels, as heretofore constructed and used, it has been necessary with some of them to have a portion of the flue leading to the chimney removable, while with others it has been necessary to lift the vessel from its place. In my improved machine, on the contrary, the delivering and the discharging flues for the flame are arranged in the same vertical plane, and the revolving-chamber or vessel is supported upon a traversing-frame, which, by preference, vibrates through an arc of a circle about a vertical axis, the axis of the revolving vessel being tangential to the arc of vibration of the frame, so that the vessel may be swung round out of its normal operative position, in which its axis is perpendicular to the vertical plane of the flues until its axis is brought parallel or nearly so with the vertical plane of the flues, in which latter position the mouth of the vessel is accessible for the perfectly-convenient charging or discharging of the metal without either removing any part of the flue or lifting the vessel, as heretofore. Moreover, in my improved machine the frame which supports the revolving vessel also carries the mechanism for revolving it; and, by preference, the steam for operating this mechanism is carried through the vertical axis about



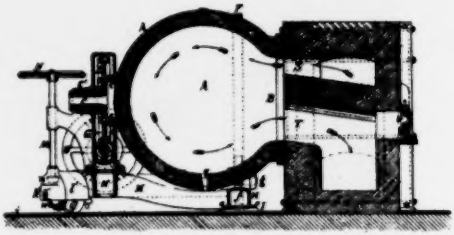
2 Sheets—Sheet 1.

WILLIAM SELLERS.

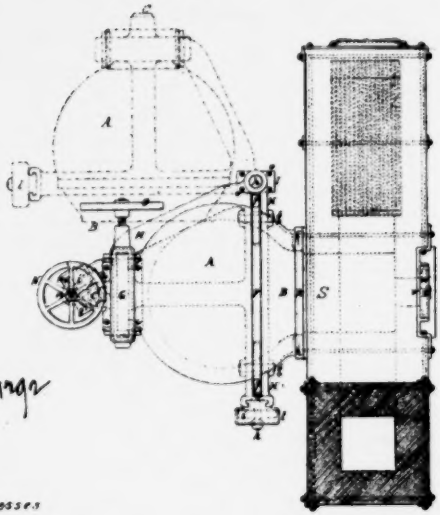
Improvement in Apparatus for Puddling Iron.

No. 124,224. Patented March 5, 1872.

— FIG. 1 —



— FIG. 2 —



Witnesses

Wm B Dayton

Wm S Lyon

Wm Sellers

by his Attorney

Henry Baldwin

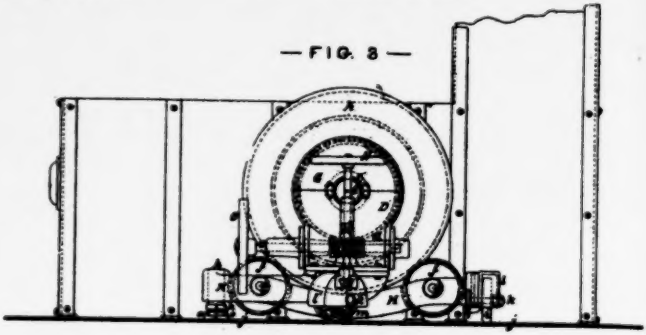
2 Sheets—Sheet 2.

WILLIAM SELLERS.

Improvement in Apparatus for Puddling Iron.

No. 124,224. Patented March 5, 1872.

— FIG. 3 —



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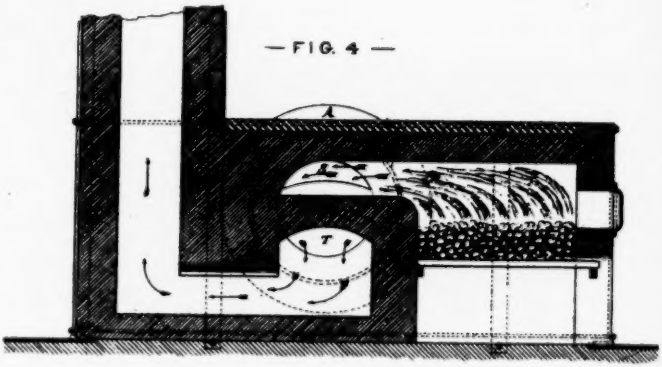
v.
Columbia Iron Co. } p. 1793.

— FIG. 4 —



Witnesses

Wm. B. Dayton

Wm. L. Layton

Wm. Sellers
by his Attorney
Henry Baltzell

which the frame vibrates, as before mentioned; and this constitutes an additional feature of my improvement.

Again, to attain in the operation of such a vessel the highest mechanical perfection it is necessary to provide against anything which might, even in degree, detract from its efficiency; and as the variations of temperature inseparable from the operation might disturb the proper relation of the parts, I provide for such adjustments of the frame which carries the vessel as will compensate any such disturbance.

(Here follow diagrams marked pp. 1292 & 1293.)

The accompanying drawing illustrates the means which, by preference, I have adopted for attaining the objects of my improvements.

Figure 1 is a sectional view of a puddling-furnace embodying my improvements. Fig. 2 is a plan of the puddling-machine, furnace-flues and chimney, showing in dotted lines the vessel or chamber in position for being charged or discharged. Fig. 3 is an elevation of the parts shown in Fig. 2. Fig. 4 is a sectional view of my improved puddling-machine in combination with a furnace.

The chamber or vessel A has, by preference, a spherical form, with a large mouth or circular opening, B, and has on its exterior a series of bosses or projections, *c c*, opposite the opening B, so arranged as to serve for securing a worm-wheel, D, to the chamber. To the worm-wheel D the hollow trunnion C is attached, which supports the chamber at that end, (the axis of this trunnion being substantially horizontal and passing through the center of the opening B.) Motion is imparted to the vessel through the worm-wheel D by means to be presently described. The object of using a hollow trunnion and bosses on the chamber is to provide for a circulation of air, which will prevent the overheating of the journal. A steel band or tire, F, is to be shrunk upon the vessel A near its open end, and concentric with the trunnion C. This vessel should be
1295 lined with some refractory material such as is technically known in the art as a "fix," which will withstand the heat and the chemical and mechanical actions involved in the process. A top-hole, *q*, passing through the vessel and through the lining, serves for withdrawing the cinder from the vessel. This tap-hole is, of course, plugged up properly during the operation of the vessel, and at all other times, except when opened for the purpose of withdrawing the cinder. A suitable floor-plate, *j*, is provided in the proper relation to the delivering and discharging flues, and of sufficient area for the traverse of a large hollow frame, H H H, which has three points of support upon the floor-plate—namely, at what I may call the inner end of this frame a pintle, *h*, resting in a step-bearing, I, about the axis of which the traversing-frame moves in carrying the chamber or vessel A from one to the other of the two positions shown in Fig. 2; and at the outer and rear ends, respectively, of the frame the two truck-wheels, *i i'*, running upon the floor-plate *j*. The axles *k k'* of these truck-wheels are placed radially to the axis of the pintle *h*, and have their bearings in vertically-adjustable

boxes *l l'*. The pintle *h* is also made vertically adjustable in this instance by being provided with a large screw-thread, which enters a corresponding thread in the frame H H H, so that, by turning the pintle within its screw-socket, the frame may be raised or lowered at will, and this pintle is fixed in its vertically-adjusted position by a set-screw. The bolt-holes provided in the floor-plate *j* and in the flange of the step-bearing I for the holding-down bolts *o o o* of the step-bearing are made oblong in directions at right angles to each other, so as to admit, also, of an adjustment of the frame horizontally in every direction by moving the step-bearing. Upon the axle *k'* of the truck-wheel *i'* I fasten securely a bevel-wheel, *m*, into which gears the pinion *n*, securely fastened upon the vertical shaft M, which is supported by the box *l'* and case G, and upon the upper end of which I place the hand-wheel N. The frame H H H can be readily moved into either of the positions shown in Fig. 2 by rotating the hand-wheel N in the requisite direction, thereby causing the truck-wheel *i'* to revolve, the frictional contact between this wheel and the floor-plate *j* being sufficient to vibrate the frame H H H about the pintle *h*. In the front cross-piece of the frame H H H I mount the guide-wheels *f f;* and at or near the rear of the frame I mount a casing, G, in which I provide a bearing for the trunnion C, and also a bearing for the shaft *e* of a worm, E, which engages in the worm-wheel D on the chamber A. This casing G incloses both the worm-wheel D and the worm-shaft *e*, protecting them from dust and admitting of their being kept thoroughly lubricated. The vessel A is placed upon the frame H H H, with its trunnion resting in its bearing in the casing G, and thus supporting the rear end of the vessel, while the guide-wheels *f f*, upon which the band or tire F rests and turns, support the forward or open end of the vessel in a position always substantially horizontal; and the vessel thus supported is free to be revolved upon its points of support through the worm-wheel.

Motion is communicated to the vessel A from a steam-engine having the axis of the cylinder horizontal, and over the axis of the pintle *h*. The connecting-rod from this steam-cylinder takes hold upon a crank-pin in the face of the balance-wheel O upon the outer end of the worm-shaft *e*. Steam is carried to this engine by a vertical steam-pipe in the line of the axis of the pintle *h*, and the exhaust is carried off through this pintle, so that the vibrations of the frame H H H cause no disturbance to either the steam or the exhaust-pipe.

I have not shown this steam engine in position, as neither it nor its arrangement forms any part of my claim, and as it will be obvious to a skilled mechanic that, by various methods other than the one described, the vessel A may be rotated, the axis of vibration of the frame H H H still serving as a point at which to introduce the power.

It will also be evident to the skilled mechanic that the frame which carries the puddling-vessel, and the mechanism for revolving the same, may be arranged in many other ways to perform the functions of moving the puddling-vessel to and from the flues

without disarranging the driving mechanism: thus, it may be mounted upon wheels on a track, either straight or curved, which may carry the vessel to a convenient point for charging and discharging, or the track may be upon a turning table, so that the vessel may be moved first at right angles to the plane of the flues, and then turned around to a convenient position for charging and discharging; and I contemplate arranging this frame to traverse in such various directions as the exigencies of the case may require without disturbing the connection between the driving mechanism upon the frame and the motive power. The course by which the flame enters and is discharged from the revolving puddling-chamber A is very clearly exhibited by the arrows in Figs. 1 and 4. I provide a door, W, at the back of the flues, through which the chamber, when in position, may be fettled or its charge rabbled, and a spy-hole, *v*, in this door to observe when the charge of metal is in condition to have the cinder withdrawn.

The mode or means by which the requisite flame used in the puddling process is to be produced forms no part of this patent, and I need not therefore describe herein the furnace represented in Fig. 4, but in all cases the openings through which the flame or gaseous fuel and the products of combustion are respectively delivered into and discharged from the vessel should be so arranged relatively to each other that they may be encircled by a flat ring, R. The surface of this ring is made sufficiently broad to correspond with the surface of the open end of the vessel A, so that when the vessel is brought up to the ring these broad surfaces, without being in actual contact, will be so close together as to prevent the escape of flame between them. The back of the ring R is so secured to the casing of the flue as to prevent the escape of gas on that side. This ring may be kept cool by the introduction of water into pipes cast within it, or may be simply cast hollow and water introduced at the bottom and allowed to flow off at the top. It is obvious that, instead of the plane surfaces above described, the surface of the ring and the face of the open end of the vessel might be made in various corresponding forms to effect the same object.

1296

Assuming the vessel A to be in the position shown by dotted lines in Fig. 2, the crude iron may be charged into it either cold or in a state of fusion. The vessel is then brought around with its open end against the ring R, and the flame or gaseous fuel admitted to the vessel. If the iron is charged in cold the vessel remains stationary until the charge is brought to a state of fusion. Assuming the iron to be in a state of fusion, the vessel is revolved slowly, while a continuous volume of flame is discharged into it through the delivery-flue S. This flame sweeps over the interior surface of the vessel and impinges upon the metal, (the surface of which is being constantly changed by the revolution of the vessel,) the products of combustion continuously passing through the discharge-flue T. In Fig. 1 the arrows show the directions of the flame into and of the products of combustion out of the vessel. The successive changes of the condition of the metal during the process are readily observed through the spy-hole *v* in the door W, and con-

trolled by regulating the volume and intensity of the flame and the speed of rotation of the vessel. When the balling is completed the flame is checked. The frame H H H with its revolving chamber A is swung away from the ring R by means of the hand-wheel N and its driving-gear, and the ball is removed; a new charge of crude iron being supplied, the open end of the vessel is again brought against the ring, and the operation of puddling is repeated.

The advantages of passing the flame into and out of the revolving chamber at one and the same opening are numerous. When the vessel has two openings, as heretofore, the escape of gas at each of them must be provided against, and this involves the necessity of adjustments not only between the ends of the puddling-chamber and the flue, respectively, but also between the furnace and the flue relatively to each other; so that the requisite adjustments cannot be obtained by any adjustment of the puddling-vessel alone; while with my improvements the provision against the escape of gas and all the adjustments required are confined to the single surface of the open end of the vessel. There being but one opening, the chance for escape of gas is diminished at least one-half; and there being but one surface, all the adjustments required may be made without any adjustment of the furnace or flue relatively to each other. The flame is also more perfectly reverberated and utilized, and in its peculiar sweeping action over the whole interior surface of the revolving chamber operates more effectually upon the charge of metal than it could in passing directly through the vessel, as heretofore.

Charging and discharging the puddling-chamber without having to lift it, and without having to remove a portion of the flue for this purpose; having the step which carries the vertical axis of the vibrating frame adjustable horizontally in every direction, and the frame adjustable vertically upon the axis about which it vibrates, and the wheels which support the vibrating frame at other points than the axis also adjustable vertically, all of these movements and adjustments being made without disturbing the connections between the vessel, the frame, the revolving mechanism, and the power, are severally and collectively advantages which must be readily appreciated.

I claim as my invention, and desire to secure by letters patent—

1. The improvement in the art of mechanical puddling, hereinbefore set forth, by delivering the flame into and discharging the products of combustion from one and the same end of a revolving puddling-vessel.

2. A revolving puddling-vessel having its axis substantially horizontal and a single opening, through which opening the flame is delivered into and the products of combustion are discharged from said vessel in the direction of its axis, substantially as hereinbefore set forth.

3. The combination of a revolving puddling-vessel having its axis substantially horizontal, and flues through which, respectively, the flame is delivered into and the products of combustion are dis-

charged from one and the same end of the revolving vessel, substantially as set forth.

4. The combination, with a revolving puddling-vessel, of a traversing supporting-frame, substantially as hereinbefore set forth.

5. The combination of a revolving puddling-vessel and a traversing supporting-frame with flues, through which, respectively, the flame is delivered into and the products of combustion are discharged from one and the same end of the revolving vessel, substantially as hereinbefore set forth.

6. The combination of a revolving puddling-vessel, a traversing supporting-frame, and mechanism by which the frame may be adjusted vertically and horizontally in every direction, substantially as set forth.

7. The combination, substantially as hereinbefore set forth, of a revolving puddling-vessel, a traversing supporting-frame, and mechanism for revolving the vessel, such revolving mechanism being mounted upon the traversing supporting-frame.

8. The combination of a revolving puddling-vessel, a traversing supporting-frame, mechanism for revolving the vessel, (such revolving mechanism being mounted upon the traversing supporting-frame,) and flues through which, respectively, the flame is
1297 delivered into and the products of combustion are discharged out of one and the same end of the revolving vessel, substantially as hereinbefore set forth.

9. The combination of a revolving puddling-vessel having its axis substantially horizontal, a traversing supporting-frame, mechanism by which the traversing supporting-frame may be adjusted vertically and horizontally in every direction, mechanism for revolving the vessel, (such revolving mechanism being mounted upon the adjustable traversing supporting-frame,) an axis about which the adjustable traversing supporting-frame vibrates, and through which the power for revolving the vessel is transmitted, and flues through which, respectively, the flame is delivered into and the products of combustion are discharged out of one and the same end of the revolving vessel in the direction of its axis, substantially as hereinbefore set forth.

10. In combination with a revolving puddling-vessel the bosses and hollow trunnion, substantially as and for the purposes set forth.

WM. SELLERS.

Witnesses:
WM. B. DAYTON.
WM. S. LYNN.

1299 UNITED STATES PATENT OFFICE.

CHARLES PERNOT, of Saint Chamond, France.

Improvement in Mechanical Puddlers.

Specification forming part of Letters Patent No. 149,517, dated April 7, 1874; application filed February 16, 1874.

To all whom it may concern:

Be it known that I, Charles Pernot, of Saint Chamond, France, have invented certain improvements in mechanical puddling-furnaces, of which the following is a specification:

My improvement relates to puddling-furnaces having movable receivers or beds; and consists in securing the bed in an inclined position on a truck, and adapting it to the inclined base of the furnace, against which it may be brought by sliding the truck forward. My invention further consists of devices for raising and rotating the receiver, as described hereafter.

(Here follows diagram marked p. 1298.)

As regards general shape, the puddling-furnace B, to which the receiver A is applied, does not differ materially from those in common use, there being the ordinary fire-place *a*, bridge-wall *b*, and flue *d*, leading to the chimney, the latter not being shown in the drawing. The base or portion of the furnace usually occupied by the bed, and situated between the front and rear bridges *b* and *b'*, has an opening, *x*, figure 1, immediately beneath which are the receiver A and its supporting-cap D, both contained within a transverse passage, *y*, extending entirely across the lower portion of the furnace. The car D has wheels or rollers *f* of different diameters, on which the receiver rests, and by which, in conjunction with a pivot-rod, *h*, connected to the short arm of a weighted lever, *i*, the said receiver is maintained in close contact with the correspondingly-inclined roof of the passage *y*. The required rotary movement is imparted to the inclined receiver by a worm, *j*, which turns in standards on the car, and gears into a worm-wheel, *k*, secured to the exterior of said receiver. The car D runs upon a track, *m*, and can, together with the receiver, be withdrawn laterally from the furnace in the direction of the arrow, Fig. 2.

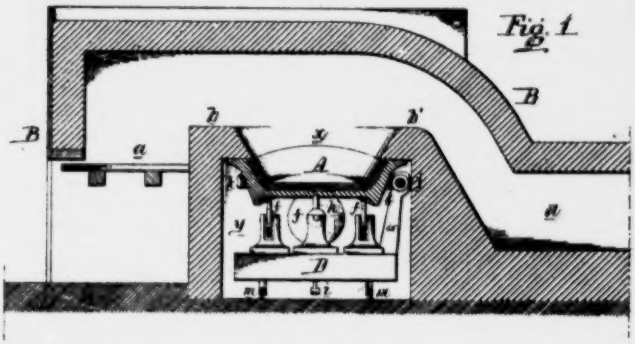
The receiver is prepared for use by lining it with sand, scrap-iron, or calcareous matter. If scrap-iron be used, it is introduced into the receiver after the furnace has been brought to a white heat, after which the flame is permitted to become clear, in order to oxidize and melt the metal. The heat is then reduced and the receiver rotated, when the oxidized metal will adhere to and form a uniform layer on the bottom and sides of the said receiver. This operation is repeated several times, until a layer of the proper thickness has been obtained, when the furnace is permitted to cool. The furnace

C. PERNOT.

Mechanical Puddlers.

No. 149,517. Patented April 7, 1874.

Fig. 1.



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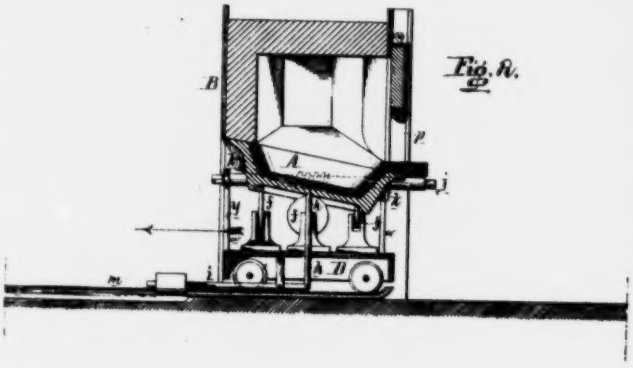
v.
Cambria Iron Co. } p. 1798.

Fig. 2.



Witnesses, Harry Smith
Thomas McElvain

Charles Pernot
by his Attys
Howson and Son.

is next brought to a white heat, and rich dross or slag and the cast-iron to be puddled are introduced into the receiver, care being taken to rotate the latter, in order to change the position of the pieces of metal, and thus heat them uniformly. After the metal has been thus treated for about half an hour the furnace is cooled, when the slag, becoming thick, will mix with the fused iron. The heat is then slowly increased and the receiver rotated, this being continued until the full heat is on, when the metal will separate from the dross, and may be taken from the furnace, either as a single bloom or ball, or after having been separated into several, by suitable tools introduced through the working-hole *p*.

The receiver, by pushing forward the truck, may be brought close against the under side of the base of the furnace, and can be readily removed and changed at any time without disturbing the fixed portions of the furnace by withdrawing it from the latter through the transverse passage *y*.

I claim as my invention—

1. The combination of a furnace having an inclined base and opening, *x*, and a truck carrying an inclined receiver, as and for the purpose described.

2. The combination of the receiver A, truck, and counterbalance-lever *i*, as set forth.

3. The combination of the truck and the inclined receiver, worm-shaft *k*, and shaft *j*, supported by standards on the truck, as specified.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

CH. PERNOT.

Witnesses:

A. WILMONT.

J. E. PAGNON.

1303 UNITED STATES PATENT OFFICE.

CHARLES WILLIAM SIEMENS, of Westminster, England.

Improvement in the Manufacture of Iron and Steel.

Specification forming part of Letters Patent No. 159,712, dated February 9, 1875; application filed May 27, 1873.

To all whom it may concern:

Be it known that I, Charles William Siemens, of No. 3 Great George street, Westminster, county of Middlesex, England, have invented an improved process and apparatus for the manufacture of iron and steel; and do hereby declare that the following description, taken in connection with the accompanying sheets of drawings hereinafter referred to, forms a full and exact specification of the same, wherein I have set forth the nature and principles of my said improvement, by which my invention may be distinguished from others of a similar class, together with such parts as I claim and desire to secure by letters patent—that is to say:

This invention relates to a process and apparatus for effecting the separation of metallic iron from ores, and forming the metal into balls which may be treated for the production of wrought-iron or puddled steel, or transferred in a heated condition to a bath of highly-heated pig metal in a separate furnace, for conversion into cast-steel, or which may be converted into cast-steel or cast metal without being transferred to a separate furnace, the conversion of crude ore into cast-steel or cast metal being, in the latter case, effected in one apparatus, and by successive steps of one operation.

For this purpose the ore to be treated is crushed and mixed with a suitable proportion of lime, manganese, or other fluxing material, according to the relative amount and nature of the gangue which the ore contains, in order to form a fluid scoria; or a mixture of ores may be employed, which produces a fusible slag without admixture of lime or other fluxing material.

The mixed material is introduced into a slowly-rotating furnace, which I will presently describe, and heated nearly to the fusing-point of the ore, whereupon is added a quantity of reducing agent, such as coal or anthracite or coke, previously crushed but not ground fine, or charcoal or wood, previously dried and cut into pieces. By the slow rotation of the furnace this carbonaceous matter becomes covered by the heated ore, with which it is gradually mingled, while fresh intensely-heated surface is being continually presented to the mixture. A very powerful reaction is thus produced, and a quantity of carbonic oxide is evolved, which, in burning with the highly-heated air supplied from a regenerator, nearly suffices to maintain intense heat in the furnace without necessitating admission of additional gaseous fuel. The reduction of the ore under these conditions is effected rapidly, the gangue combining with the fluxing material, so as to form a fusible slag; and the rotation of the

3 Sheets--Sheet 1.

C. W. SIEMENS.

Manufacture of Iron and Steel.

No. 159,712. Patented Feb. 9, 1875.

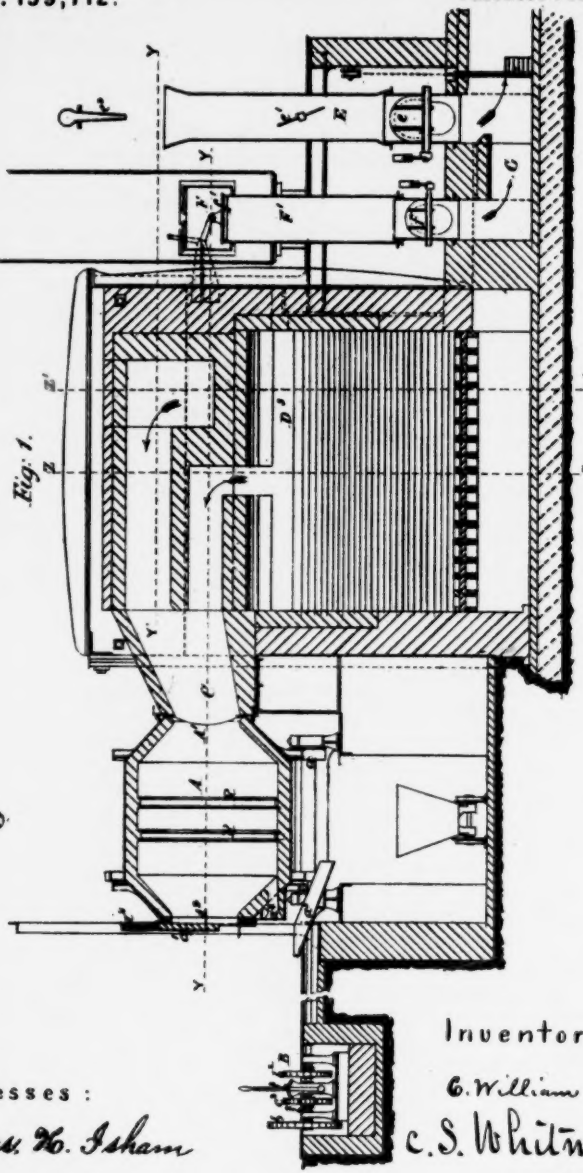


Fig. 1.

Witnesses:

Chas. H. Isham

H. A. Daniels

Inventor:

C. William Siemens by

C. S. Whitman

Attorney.

3 Sheets--Sheet 2

C. W. SIEMENS.

Manufacture of Iron and Steel.

No. 159,712. Patented Feb. 9, 1875.

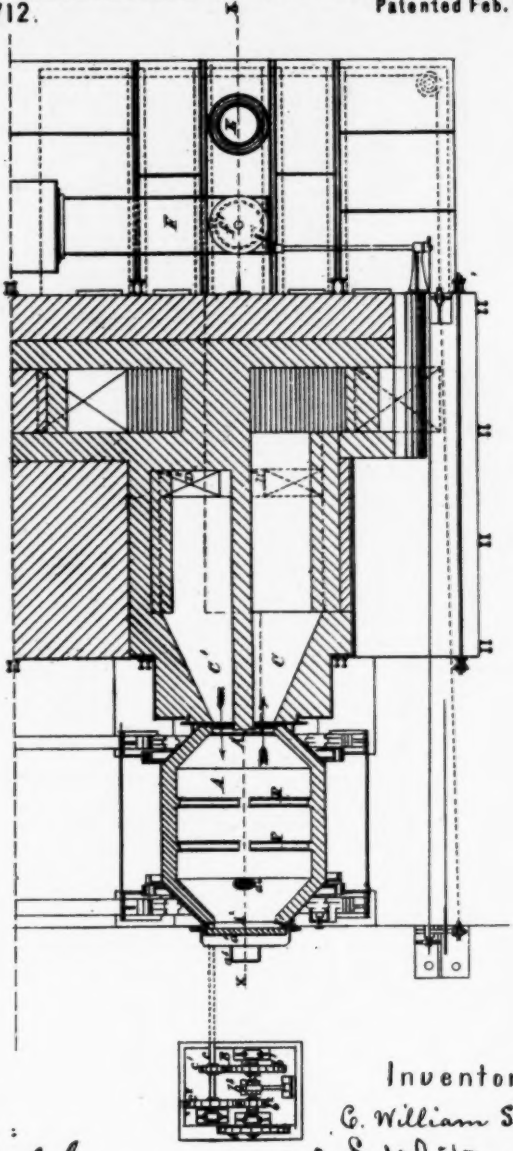


Fig. 8.

Carnegie Steel Co. } p. 1201.
Cambria Iron Co.

Witnesses:

Chas. H. Isham

H. A. Daniels

Inventor:

C. William Siemens

by C. S. Whitman

Attorney

3 Sheets--Sheet 3.

C. W. SIEMENS.

Manufacture of Iron and Steel.

No. 159,712. Patented Feb. 9, 1875.

Fig. 3

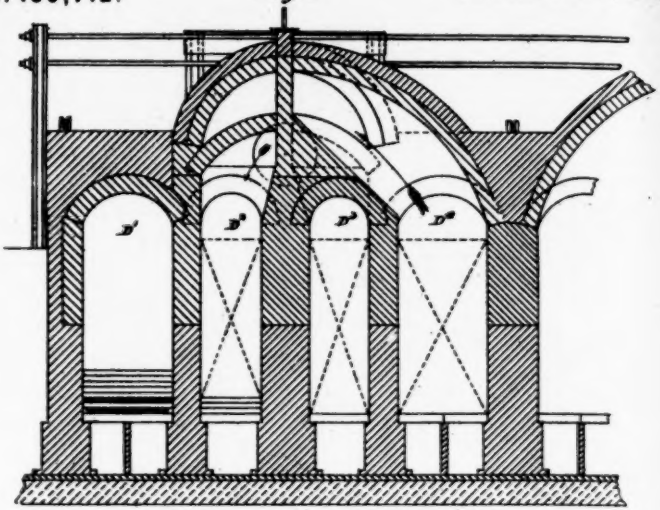
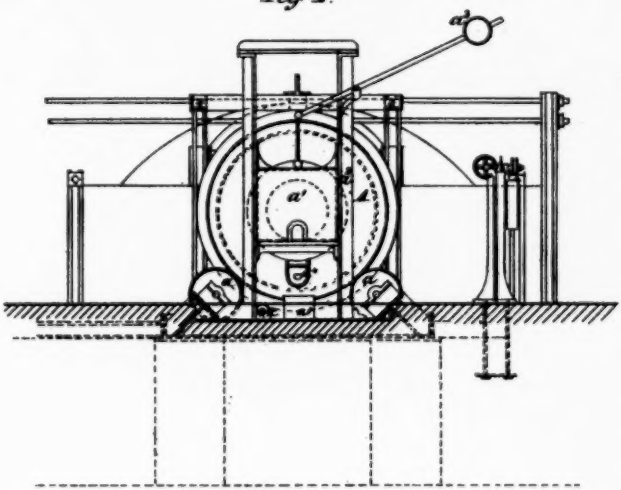


Fig. 4.



Witnesses:

Chas. H. Isham

H. A. Daniels

Inventor:

C. William Siemens

C. S. Whitman

Attorney.

furnace being very slow, (from four to six revolutions per hour,) the particles of metallic iron in course of separation are not prematurely agglomerated.

When the reaction is complete, the rotation of the furnace is stopped, and the scoria is tapped off, so as to liberate the metallic iron resulting from the reaction. A fuller supply of gaseous fuel is then turned on, and the furnace is caused to rotate five or six times more rapidly than before. This more rapid rotation has the effect of agglomerating the iron into balls, which may be taken out of the furnace and subjected to the action of squeezers, hammers, or rolls, for the production of wrought-iron or puddled steel, or which may be transferred, while hot, to a bath of highly heated pig metal for the production of cast-steel; or the balls, without being removed from the furnace, may be converted into cast-steel, or into a pure cast metal intermediate between cast-steel and cast-iron in the following manner:

After the balls are formed, the rotation of the furnace is again stopped, and the fluid scoria is again tapped off, whereupon the furnace is again caused to rotate slowly. Some hard carbonaceous substance, such as crushed anthracite or coke, is then introduced, while the heat of the furnace is raised to a high intensity. The balls, combining with the carbon, become fused into a fluid mass, which can be tapped and cast into forms or molds; or, instead of introducing hard carbonaceous substances to effect the fusion of the balls, broken pig metal, or spiegeleisen, or ferro-manganese may be employed for the same purpose, spiegeleisen or ferro-manganese being especially desirable or necessary if malleable cast-steel is to be produced.

The proportion of the carbonaceous matter required for the conversion of a certain quantity of ore depends upon the rich-
1304 ness of the ore, and upon the nature of the carbonaceous matter employed, as well as on the nature of the iron or steel to be produced. In each case the proportions should be determined by experience; but under ordinary circumstances about half a ton of solid carbonaceous matter to the ton of metal to be produced will be found sufficient. If the reducing agent employed be anthracite or hard coke, it may be crushed moderately fine and charged into the furnace with the ore, and heated simultaneously therewith.

In effecting the process as described above, I employ a rotative regenerative gas-furnace, constructed and arranged as shown on sheets I, II, and III of the accompanying drawings.

(Here follow diagrams marked pp. 1300, 1301 & 1302.)

Figure 1, sheet I, represents a longitudinal section on line X X, Fig. 2. Fig. 2, sheet II, represents a sectional plan on lines Y Y Y′ Y′, Fig. 1. Fig. 3, sheet III, represents on the left-hand side a half transverse section on the line Z Z, Fig. 1, and on the right-hand side a half transverse section on the line Z′ Z′, Fig. 1; and Fig. 4, sheet III, shows a front view.

A is the rotative furnace, in shape cylindrical, with truncated

conical ends. It is mounted on rollers *a a*, which are caused to revolve by gearing B, driven by any suitable power. The gearing B is arranged with clutch apparatus, so that the furnace can be rotated at either the slow or the quick speed above referred to, or brought to rest while the prime mover continues to work at its regular speed. For this purpose the gearing B consists of a wheel, b^1, and pinion b^2, loose on the shaft of the driving-wheel *b*, and gearing respectively with pinion c^1 and wheel c^2 on shaft *c*, which drives the rollers *a*. By means of a clutch b^3, either the wheel b^1 or the pinion b^2 is geared with the driving-shaft, and thus a slow or a quick speed is imparted to the rotative furnace; or, by throwing the clutch out of gear, the furnace is brought to rest. The throat of the furnace at A^1 is in communication with two flues, C and C′, each of which has two branches, communicating, respectively, with two of four regenerative chambers, D^1 D^2 D^3 D^4. The outer regenerative chambers, D^1 D^4, are for heating the air, and the two inner chambers D^2 and D^3, are for heating the gas supplied to the furnace. The air is supplied by a main duct, E, provided with a reversing-valve *e*, by which the supply can be turned toward either of the chambers D^1 or D^4, and with a throttle-valve, e^1, whereby the supply can be regulated. In order to increase the flow of air when intense heat is required in the furnace, a jet of compressed air, e^2, is introduced from a blast-pipe into the middle of the duct E.

The gas from the main supply-trunk F is introduced by a duct F′, which is provided with a stop-valve, *f′*, and with a reversing-valve, *f*, whereby the gas can be directed to either of the chambers D^2 or D^3. The air and gas thus supplied to the two regenerative chambers on the one side of the structure flow thence, heated, into one of the flues C or C′, where they mingle and produce a powerful flame, which plays into and sweeps round the furnace A, the products of combustion escaping by the other of the flues C or C′, through the other two regenerative chambers, and thence, by a flue, G, to a chimney or other outlet.

When one of the two pairs of regenerative chambers has been sufficiently heated by the escaping products of combustion, and the other pair cooled by passage of the incoming air and gas through them, the valves are moved so as to alter the direction of the inflowing and outflowing currents, in the manner well understood in reference to the working of regenerative gas-furnaces.

At the end, A^2, of the furnace opposite the throat is mounted, between guides a^2, a vertically-sliding door, a^1, with a counterbalance-weight, a^3. At the front of the furnace is formed a tap-hole, a^4, which can be plugged with refractory material, and under this there is a chute, a^5, by which material tapped from the furnace can be run into forms or molds, or into a truck in a pit below the furnace.

The lining of the furnace A may be of any known suitable refractory material that is not readily affected by scoria; but I prefer to use for it a lining formed in the following manner: I take the mineral known as bauxite, consisting chiefly of alumina, with a proportion of peroxide of iron. I calcine it and reduce it to powder,

and mix with it from ten to fifteen per cent. of powdered plumbago, graphite, or other carbonaceous matter in a dense form, and such a quantity of argillaceous clay or other binding material as is necessary to give cohesion. I form this mixture into bricks or blocks of suitable form, and burn them in a kiln, in the usual way. In burning such bricks the oxide of iron contained in the bauxite is converted by the carbonaceous matter into metallic iron, and a very refractory material is thus produced, capable of resisting the action of scoria for a considerable time.

These bricks may be built inside the rotating furnace, with cement made from the above-named mixture, used in an unburnt condition; but I prefer to build them in loosely, and, after heating the furnace to a white heat, to charge it with pure ore or hammer-slag, while rotating slowly. The ore or slag is melted, and sinks into the crevices between the bricks, serving as a cement, which binds them firmly together, and also as a glaze, which prevents access of air to the interior of the bricks.

When the bricks are so cemented, the excess of fused ore or slag is tapped off, and the furnace is ready for work.

In employing it for effecting the process described above, a quantity—say one ton—of the mixed ore and flux is introduced by the door, which is then closed, and the furnace is made to rotate at its slow speed for about half an hour, till the mass becomes thoroughly heated to near its fusing-point. The reducing material, being then introduced, is gradually covered by the ore as it falls to the
1305 bottom of the furnace during rotation, and a rapid reducing action ensues. As carbonic oxide is evolved, a full supply of heated air is given to effect its combustion, the supply of gas coming from the regenerator being at the same time reduced or nearly stopped. In about one hour, the reduction is completed, the furnace is stopped with its tap-hole undermost, and the liquid scoria is tapped off, after which the full supply of producer-gas is given, and the furnace is caused to rotate at its rapid speed, whereby the precipitated metal is quickly balled.

In order to produce several balls of moderate size, instead of one large ball, which would be inconvenient to handle, I form internally-projecting circular ribs R in the lining of the furnace, which have the effect of dividing the mass, during balling, into several portions. A portion of these ribs is omitted in the line of the tap-hole, as shown in Fig. 2, so that there may be a clear passage for material to flow toward the front of the furnace when the tap-hole is opened.

The balls may be treated for wrought-iron or puddled steel by hammers, squeezers, or rolls, or they may be fused with pig metal, spiegeleisen, or ferro-manganese, for the production of cast metal or cast steel, as above described.

Having thus described the nature of my invention, and the manner in which the same is to be practically carried out, I claim—

1. The method of effecting the separation of metallic iron from heated ore mingled with fluxing materials, by causing carbonaceous matter to be mixed therewith by means of the slow rotation of a

rotative furnace, and forming the separated metal, by means of a quicker rotation, into balls, for the production of wrought-iron or puddled steel, or for the production of cast-steel by the employment of a separate furnace, substantially as herein described.

2. The method of separating metallic iron from ore, in the manner and by the means above referred to, and converting the separated metal into cast-iron or cast-steel, in one and the same rotative furnace, by the further addition of solid carbonaceous matter, cast-iron, speigeleisen, or ferro-manganese, substantially as herein described.

3. A rotative regenerating gas furnace for the manufacture of iron and steel, wherein the heated air and gas are admitted, and the products of combustion are emitted, at the one end or throat of the rotative furnace, and a working-door is provided at the other end, substantially as hereinbefore described with reference to the accompanying drawings.

In testimony whereof I have signed my name to this specification in presence of two subscribing witnesses this 21st day of February, 1873.

C. WILLIAM SIEMENS.

Witnesses:
CHAS. D. ABEL.
THOMAS TAYLOR.

2 Sheets--Sheet 1.

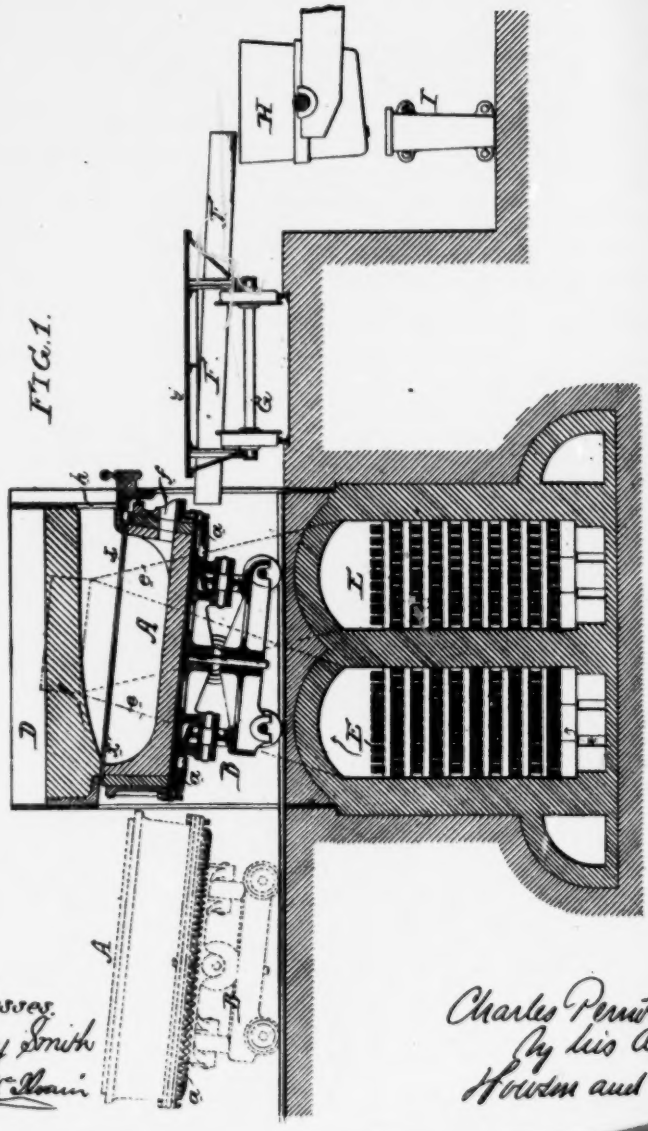
C. PERNOT.

Inclined Revolving Puddling Furnace.

No. 169,033. Patented Oct. 19, 1875.

Carnegie Steel Co. v. Cambria Iron Co. } p1306.

FIG. 1.



Witnesses.
Harry Smith
Thos. McKeown

Charles Pernot
by his Atty
Howson and Sa

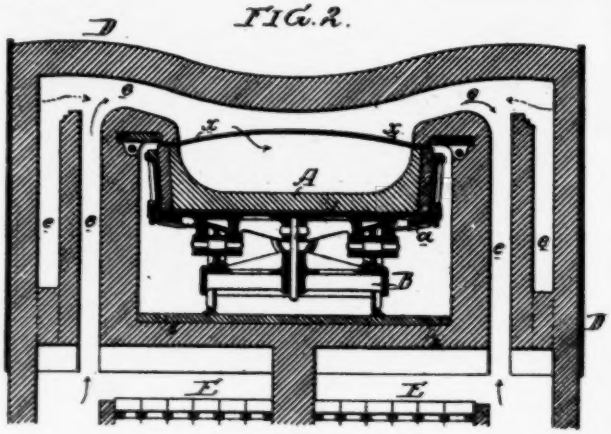
2 Sheets--Sheet 2.

C. PERNOT.

Inclined Revolving Puddling Furnace.

No. 169,033. Patented Oct. 19, 1875.

FIG. 2.



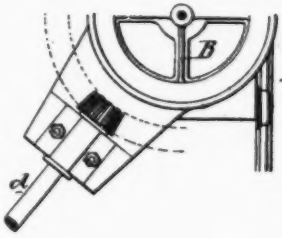


FIG. 3.

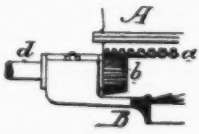


FIG. 4.

Carnegie Steel Co. } p. 1207
Cambria Iron Co. }

Witnesses, Harry Smith
Thomas McIlvain

Charles Pernot
by his Attys
Howson and Son

1308 UNITED STATES PATENT OFFICE.

CHARLES PERNOT, of St. Chamond, France.

Improvement in Inclined Revolving Puddling-furnaces.

Specification forming part of Letters Patent No. 169,033, dated October 19, 1875; application filed June 29, 1874.

To all whom it may concern:

Be it known that I, Charles Pernot, of St. Chamond, France, have invented an improvement in apparatus for converting iron into steel, of which the following is a specification:

The object of my invention is to improve the construction of converting-furnaces having inclined and removable hearths A, arranged as shown in the drawing.

(Here follow diagrams marked pp. 1306 and 1307.)

The hearth or receiver A is mounted in an inclined position on a truck, B, on which it can be freely rotated, the said truck being adapted to a railway-track, upon which it can, together with the receiver, be withdrawn laterally from the furnace, as indicated by dotted lines in Fig. 1.

The receiver has on its under side a cog-wheel, *a*, into which gears a pinion, *b*, on an inclined shaft, *d*, (shown in the detached views, Figs. 3 and 4 of the drawing,) the said shaft being operated, by any suitable means, in such a manner as to impart a continuous rotary movement to the inclined hearth, and in such a manner, also, that the speed can be increased or diminished at will.

In order to avoid the necessity of packing the joint *x* between the receiver and the furnace D, I employ for heating the furnace a system of regenerators, E, similar to those of a Siemens furnace, in which the internal pressure exceeds that of the external air. The joint *x*, therefore, may be left open, without any packing, the internal pressure effectually preventing the access of external air to the contents of the furnace.

While a packing round a rotary hearth is always objectionable, and generally inefficient, it is specially so where, as in this instance, the hearth is to be withdrawn from the furnace from time to time.

The receiver has a tapping-hole, *f*, for discharging the molten steel into an inclined spout, F, on a truck, G, which can be wheeled to different points, in order to be brought opposite ladles H, from which the metal is poured into ingot-molds I. (See Fig. 1.) The truck G is also constructed with a platform, *g*, above the spout, upon which the attendants can stand when charging the receiver A, or while engaged at the working-hole *h*.

The molten cast iron, by the action of the rotating hearth A, is thrown outward and upward by centrifugal force, and falls again toward the center in small particles, so that the whole of the mass is

acted on by the gases, oxidation rapidly takes place, and the required proportion of carbon is dissipated, the result being a perfectly homogeneous steel.

I do not claim a furnace having a removable rotary inclined hearth, as this is shown in the letters patent of the United States issued to me on the 7th day of April, 1874. Nor do I claim the combination of a furnace and a Siemens regenerator; but

I claim—

1. A furnace in which are combined an inclined rotating and removable hearth, arranged to leave an open joint, *x*, between the hearth and the body of the furnace, and a regenerator from which heated gases are passed to the furnace under a pressure greater than that of the external atmosphere, for the purpose specified.

2. The combination of the furnace D, inclined rotary hearth A, series of ladles H, and spout F, mounted on a truck, G, to conduct the molten metal to any one of the ladles, as set forth.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

PERNOT, CH.

Witnesses:
J. E. PAYNE.
PROSSARD.

1310 UNITED STATES PATENT OFFICE.

GEORGE H. SELLERS, of Wilmington, Delaware, assignor to William Sellers and John Sellers, Jr., of Philadelphia, Pennsylvania.

Improvement in Revolving Puddlers.

Specification forming part of Letters Patent No. 172,508, dated January 18, 1876; application filed November 24, 1875.

To all whom it may concern:

Be it known that I, George H. Sellers, of the city of Wilmington, New Castle county, Delaware, have invented a new and useful improvement in the operation of rotating puddling vessels, of which improvement the following is a specification:

My invention relates to the operation of puddling-vessels rotating about a horizontal axis, and having fixed flues for the supply of flame or fuel and the discharge of the products of combustion.

As heretofore constructed, these vessels, whether open at both ends or at one end only, have had the joints between the rotating vessel and the fixed flues formed by broad rings on the end or ends of the vessel, and on the face or faces of the flues, the breadth given to the surfaces of the joint being designed to prevent the escape of flame between these surfaces, which could not be brought into actual contact. In most cases one and generally all of these broad-surfaced rings have been provided with water circulation to lower the temperature of the joints, it having been the theory of operation in such machines that these provisions were essential to the maintenance of a practical joint. In practice, however, I have discovered that broad surfaces and lowered temperatures do not conduce to the maintenance of a proper joint, but that on the contrary they are mainly the occasion of the difficulties which have been encountered in maintaining such joints, and that this difficulty arises from the following facts: During the boiling-stage of the puddling operation the charge swells, and, overflowing the mouth of the puddling-vessel, backs up on the bottom of the flue, and across the joint between the flue and the vessel. As the iron comes to nature the charge subsides, and the liquid mass gradually retires within the vessel, the joint being close enough to retain the expanding and subsiding overflow within the flue and the vessel, yet not so close but that some portion of it will penetrate the joint, so that with the broad joint, and the lowered temperature induced thereby, whether with or without the water circulation, the cinder which penetrates the joint is chilled therein, clings to the surfaces thereof, and accumulates upon itself as the operation continues, the accretion building irregularly around the revolving surface, and almost entirely upon the lower side of the stationary surface, the whole of it attaining a degree of toughness which renders its removal extremely difficult after the operation is completed. In its conditions during the puddling operation this viscous accumulation produces great friction,

and causes a gradual enlargement of the joint upon one side. To resist this tendency great pressure has been resorted to, and this pressure, while measurably retarding the enlargement, greatly increases the friction and consequent loss of power.

It is the object of my invention so to apply my aforesaid discovery as to avoid the difficulties heretofore encountered without resorting to such pressure as has heretofore been employed; and in actual practice I have accomplished this object in such a manner as to materially improve the operation of puddling, as well as the operation of the rotary vessel itself.

My invention consists in maintaining the joint-surfaces between the revolving furnace and its fixed flues at a temperature so high as will not only prevent the overflowing cinder which penetrates the joint from becoming cold and tough enough to build up on the surfaces of the joint, but, by avoiding the chilling of this cinder, to keep it in so friable a condition that it will be ground up between the surfaces of the joint, and, instead of building up irregularly upon the joint, it will be discharged therefrom in small grains or powder; and this I accomplish (without any change in the character, supply, or application of the flame or fuel) by dispensing with any cooling circulation about the joint, and by making the surfaces of the joint-rings on the open ends of the vessel, and on their corresponding flues, narrower than those heretofore employed.

In the practice of my invention the joint-surfaces should be maintained at or near a red heat, and that they may withstand such temperature without the aid of a water circulation, and resist the wear from the cinder to which they are exposed during the operation of the machine, I prefer to make the rings of wrought-iron or steel.

1311 I have found that, in the use of a puddling-vessel such as shown in the accompanying drawings, with gaseous fuel, a joint the surfaces of which had a breadth of one and a half inch meets all the requirements of the improved operation, and accordingly I give this as a proper width for the purpose. Of course a greater or less breadth may be found compatible with the maintenance of the proper conditions of the joint and the cinder, as above set forth; but all such variations will be comprised within the knowledge of the constructor or operator.

In the accompanying drawings,

(Here follows diagram marked p. 1309.)

which form part of this specification, figure 1 represents a longitudinal elevation, in section, of a puddling-vessel and its flues, constructed as described in letters patent No. 159,849, granted to myself and Wm. Sellers, of Philadelphia, Pennsylvania, February 16, 1875, except that the joint-rings are modified in accordance with my present invention. Fig. 2 is an elevation of the joint-rings, with the base-plates to which they are attached. Fig. 3 is an enlarged section of the ring and base-plate, showing the mode of attachment.

The base-plate A encircles the mouth of the puddling-vessel, and

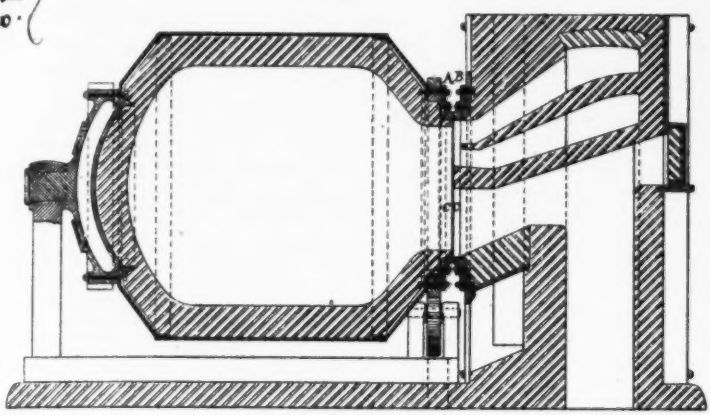
G. H. SELLERS.

REVOLVING PUDDLERS.

No. 172,508. Patented Jan. 18, 1876.

Carnegie Steel Co. v. Cambria Iron Co. p. 1309.

— Fig. 1. —



— Fig. 2. —

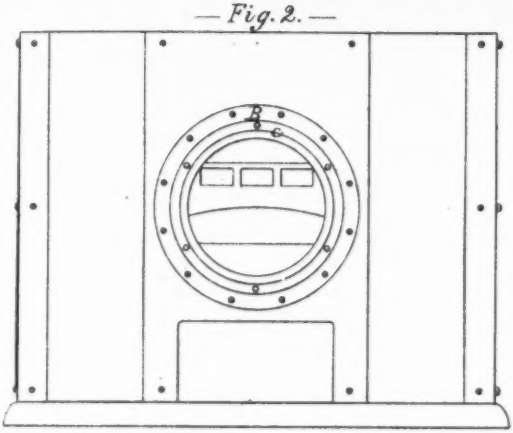


Fig. 3.

Witnesses:
Jno. C. Fraley.
James McConaghy

Inventor
Geo. H. Sellers
by Henry Baldwin Jr.
Atty

a similar one, B, incloses the flues, through which flues the flame or fuel enters the vessel, and the products of combustion are discharged. To these base-plates I secure the joint-rings C C, preferably by rivets, in such manner that they can be conveniently removed. The rings are flanged to afford a means of securing them to the base-plates without exposing the fastenings to wear during the operation of the machine.

When the rotating puddling-vessel is open at both ends it is only necessary that all the joint-rings should be constructed and operated substantially as hereinbefore set forth, and I contemplate the application of my invention, in the manner described, to such vessels.

Having thus described the nature and object of my invention, what I claim as new, and desire to secure by letters patent, is—

The method, substantially as described, of preventing the accumulation of cinder between the joint-surfaces of rotary puddling-vessels, which method consists in maintaining the joint-surfaces at so high a temperature as to keep the penetrating cinder in a friable condition during its passage between the said joint-surfaces, whereby this cinder is prevented from building up irregularly, and is ground between and discharged from the joint.

GEO. H. SELLERS.

Witnesses:
ALBERT W. SMITH.
J. ERNEST SMITH.

1314 UNITED STATES PATENT OFFICE.

RICHARD M. ATWATER, of Millville, N. J., assignor to himself and Whitall, Tatum & Co., of Philadelphia, Pa.

Improvement in the Manufacture of Glass and Furnaces Therefor.

Specification forming part of Letters Patent No. 212,168, dated February 11, 1879; application filed January 9, 1879.

To all whom it may concern:

Be it known that I, Richard M. Atwater, of Millville, Cumberland county, New Jersey, have invented a new and useful improvement in and furnaces for the manufacture of glass, of which the following is a specification:

The main object of my invention is the saving of time, fuel, and fluxes in glass-houses, by melting a batch of glass ingredients in one furnace at the high temperature demanded for the first melting, and then discharging the molten glass into a separate working-furnace, where the more moderate heat required in working the glass may be employed.

Another object of my invention is to utilize the waste heat of the working-furnaces by combining a tempering oven or ovens with the same, in the manner described hereinafter.

It has heretofore been usual to melt the batches of glass ingredients in crucibles in the same furnace from which it is gathered by the workmen. This plan is objectionable for several reasons, the most prominent of which is the large extent of space required for the crucibles, and the consequent demand for the consumption of a large amount of fuel and fluxes.

In carrying my invention into effect, I prefer the apparatus illustrated in the accompanying drawings, in which—

(Here follow diagrams marked pp. 1312 & 1313.)

Figure 1, sheet 1, is a plan view showing the melting-furnace, one working-furnace, a tempering-oven, and part of a second working-furnace; Fig. 2, sheet 2, a vertical section, drawn to an enlarged scale, on the line 1 2, Fig. 1, looking in the direction of the arrow, and showing the melting-furnace partly in section; Fig. 3, a transverse section on the line 3 4, Fig. 2; and Fig. 4, sheet 1, a vertical section of the tempering-oven.

While the melting-furnace may be fixed, I prefer to make it movable, for reasons explained hereinafter.

This furnace A is made in the present instance cylindrical in the middle, and with opposite tapering ends, and consists of substantial iron plates properly lined with refractory material, the furnace being supported by rollers *a*, so that it can be turned at pleasure.

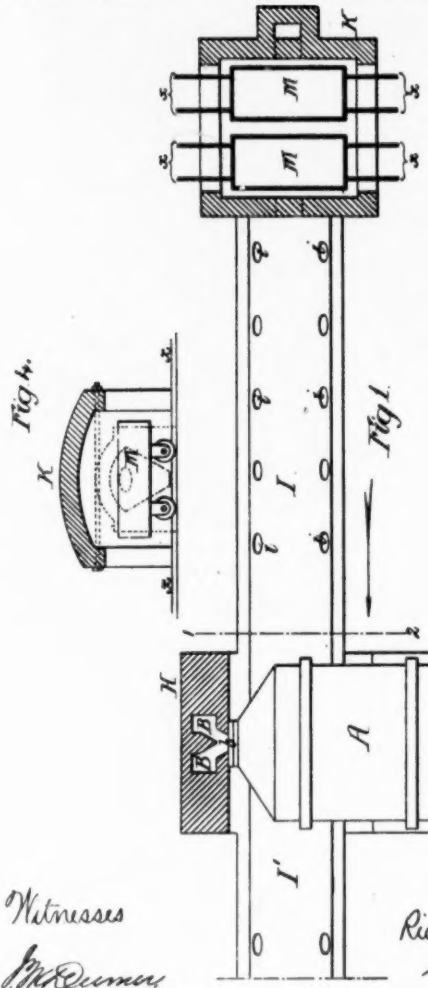
The furnace has at one end a central opening, *b*, communicating

2 Sheets—Sheet 1

R. M. ATWATER.

Manufacture of Glass and Furnaces Therefor.

No. 212,168. Patented Feb. 11, 1879.



Witnesses

J. M. Deemer

Harry Smith

Inventor

Richard M. Atwater

by his Attorneys

Howson and Sons

2 Sheets—Sheet 2.

R. M. ATWATER.

Manufacture of Glass and Furnaces Therefor.

No. 212,168. Patented Feb. 11, 1879.

Fig. 2.

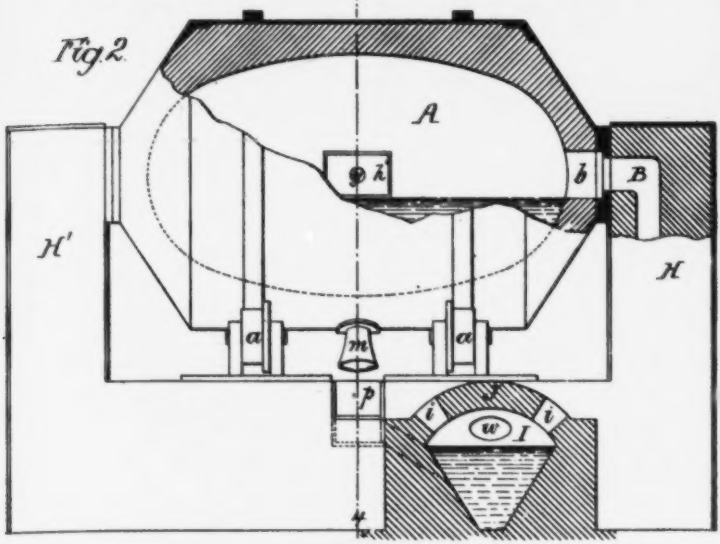
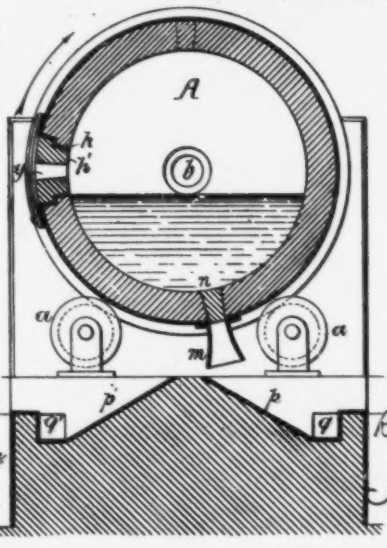


Fig. 3



Carnegie Steel Co. p. 1213
Cambria Iron Co.

Witnesses
J. M. Deemer
Harry Smith

Inventor
Richard M. Atwater
by his Attorneys
Howson & Son

with the two passages B B′, Fig. 1, in the brick-work H, and at the opposite end a like opening, *b′*, communicating with the passage D in the brick-work H′.

The furnace is charged with a batch of glass ingredients through an opening, *h*, which is furnished with a suitable detachable cover, *h′*, lined with refractory material.

Inflammable gases from a generator are directed through one of the passages B into the furnace, and heated air through the adjoining passage, these elements combining at the entrance of the furnace and producing an intense heat, which acts directly on the batch of glass ingredients. The products of combustion, which finally escape through the central opening, *b′*, may be employed to heat the volumes of air or gas, or both, prior to their introduction into the furnace, in a manner which is too well known in connection with other furnaces to need description here.

The upper portion of the batch of glass and the lining of the furnace above the same necessarily become more intensely heated than the lower portion of the batch and the lining below it. To compensate for this, and in order to subject the entire batch to the same temperature, or nearly so, and facilitate the melting and clearing operation, the furnace is turned on its rollers to the extent of one-half of a revolution at suitable intervals. This brings the highly-heated portion of the lining in direct contact with that portion of the batch which had previously received the least heat. At the same time the pasty semi-fluid glass adhering to the lining, as the furnace is turned, is exposed to the direct action of the flame in a condition most favorable to quick and thorough melting and clearing and this action may be further promoted by making the inner surface of the lining rough or corrugated.

From opposite sides of the structure which supports the melting-furnace extend the two working furnaces or troughs I I′, each of which, as seen in the transverse section, Fig. 2, is made with sides converging from the top, which has an arched roof, J, having working-holes *i* through which the workmen gather the
1315 glass. When one of these troughs—say the trough I—has to receive a supply of molten glass from the furnace A, the latter is turned until the spout *m* is in the position shown in Fig. 3, and the fire-clay plug which closes the opening *n* in the lining communicating with the spout is removed, after which the contents of the furnace will flow down the inclined plane *p* and through the passage *q*, or through other convenient channels, into the trough I, after which the opening *n* may be replugged, the furnace recharged, and the melting of the second batch may be proceeded with as before, while the workmen stationed near the working-holes proceed with their duties.

It is here where economy of time becomes most apparent, for there is no waiting on the part of workmen for batches of glass to melt, as is the case with ordinary furnaces, and there is always a new batch of melted glass ready when that in the trough has been exhausted.

I prefer to furnish the tapping-hole *n* with a plug so fitted to the

lining that it can be readily driven inward when the glass has to be withdrawn from the furnace.

A flame derived from combined air and gas enters each trough through an opening, *w*, at the end nearest the melting-furnace, and, if desired, at other suitable points, and this flame is continued through the trough, where it acts on the surface of the glass, and finally escapes at a reduced temperature into the tempering-chamber K, and thence through a chimney or other suitable outlet.

On the floor of this chamber are one or more tracks, *x*, (two in the present instance,) adapted to the wheels of metal cars M, which can be introduced into and withdrawn from the chamber through openings on opposite sides of the same, each opening being provided with suitable sliding or otherwise movable doors.

When the working-trough is in operation, one of the cars is always in the tempering-chamber, the doors of the latter being closed, and the articles of glass, as fast as they are blown, pressed, or molded, are placed in the car through a suitable opening in the brick-work above the door or in the door itself.

When the car is full, a suitable cover is placed over it, or sand is deposited on the articles, so as to exclude the air, after which the car is moved to any out-of-the-way place, in order that its contents may be gradually cooled, an empty car being introduced into the chamber for receiving another lot of glass objects.

Returning to the working-trough, it should be understood that the supplies of air and gas are so graduated that the heat will not be as intense as in the melting-furnace, for in order to properly work glass it must be maintained at a much lower temperature than is required to melt it in the first instance, the temperature required for melting the batch of glass ingredients being 2,400° Fahrenheit, and that for maintaining the glass in a proper condition for being worked 1,400° Fahrenheit.

The heat being applied to the upper surface only of the glass in the trough, no impurities can rise, and there will be an absence of blisters.

The shape of the trough as illustrated is desirable, as it insures the presentation of an extended surface area of glass to the flame. The shape, moreover, tends to preserve the integrity of the interior of the trough, and renders the detaching of particles of the lining difficult.

The shape and size of the trough will demand more or less alteration when large masses of glass have to be gathered, as in the manufacture of carboys and window-glass.

Another advantage of the peculiar shape of the working-trough is, that when the glass is reduced in quantity, it occupies a contracted space, and hence there is less waste than if the furnace had vertical sides.

It may be remarked here that the working furnaces or troughs should be heated before glass is introduced into them.

There should be in the melting-furnace, and preferably in the cover *h'* of the feed-opening, a spy-hole, *y*, which is always above the surface of the glass, the furnace being turned from the position

Fig. 3 in the direction of the arrow to the extent of one-half only of its circumference, and then back again at such intervals as the condition of the charge may suggest.

The molten glass may be removed from the melting-furnace through the charging-opening, if desired.

I claim as my invention—

1. As an improvement in preparing glass for being manufactured into different articles, first melting the glass in one furnace at a high temperature, and then tapping the contents into a separate and independent working furnace or trough maintained at a lower temperature, substantially as set forth.

2. The mode described of melting glass—that is to say, causing the heated lining of the furnace above the body of glass to take, at intervals, a position below the same, while the surface is acted upon by a flame, substantially as described.

3. The combination of a movable melting-furnace with a working trough or troughs, into which the contents of the furnace can be discharged.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

RICHARD M. ATWATER.

Witnesses:

WILLIAM COOPER.

HARRY SMITH.

1320 UNITED STATES PATENT OFFICE.

WILLIAM HAINSWORTH, of Pittsburg, Pennsylvania.

Bessemer Plant and Apparatus.

Specification forming part of Letters Patent No. 238,110, dated February 22, 1881. Application filed December 30, 1880. (No model.)

To all whom it may concern:

Be it known that I, William Hainsworth, of Pittsburg, county of Allegheny, State of Pennsylvania, have invented or discovered a new and useful improvement in Bessemer plant and apparatus; and I do hereby declare the following to be a full, clear, concise, and exact description thereof, reference being had to the accompanying drawings, making a part of this specification, in which—like letters indicating like parts—

(Here follow diagrams marked pp. 1316 to 1319, incl.)

Figure 1, sheet 1, is a plan view or diagram of the ground-floor arrangement of a Bessemer plant. Fig. 2, sheet 2, is a vertical section of the plant and its accessories in the plane of the line *x x* of Fig. 1. Fig. 3 is a like sectional view in the plane of the line *x' x'* of Fig. 1. Fig. 4, sheet 3, is a view, to an enlarged scale, of the car used in the moving of ingots, and onto which they are loaded or discharged directly from the molds, the latter, as also the casting-ladle, being represented chiefly in section, but partly in elevation. Fig. 5 is a transverse section, through the bottom of the ingot-frame and ingot-molds, of Fig. 3; and Figs. 6, 7, and 8 of sheet 4 illustrate a modified construction of apparatus for the casting, disposing of and handling ingots.

At B, I have represented an ordinary Bessemer converter, suspended by trunnions and adapted to be rotated, in the usual way and for the usual purposes, by a hydraulic apparatus, *b*, and with the usual air-blast and valve-connections, as at *b'*.

Two cupolas or iron-melting furnaces are shown at A A', the nearer one, A, being the one ordinarily used, and the farther one, A', being designed for use in case of injury to the first one. Two spiegel furnaces or cupolas are represented at A^2, which may be of the usual or any known construction. All these cupolas are preferably arranged along near a circular line, *a'*, Fig. 1, which may represent the sweep of a crane, *a*, properly arranged and constructed for carrying thereon a ladle from any of the cupolas A' A^2 to a point convenient for pouring or running its contents into the converter-mouth.

B' is a pipe into which the converter discharges during the blowing operation, and which, instead of being of the form or construction of an ordinary chimney and hood, as heretofore, is

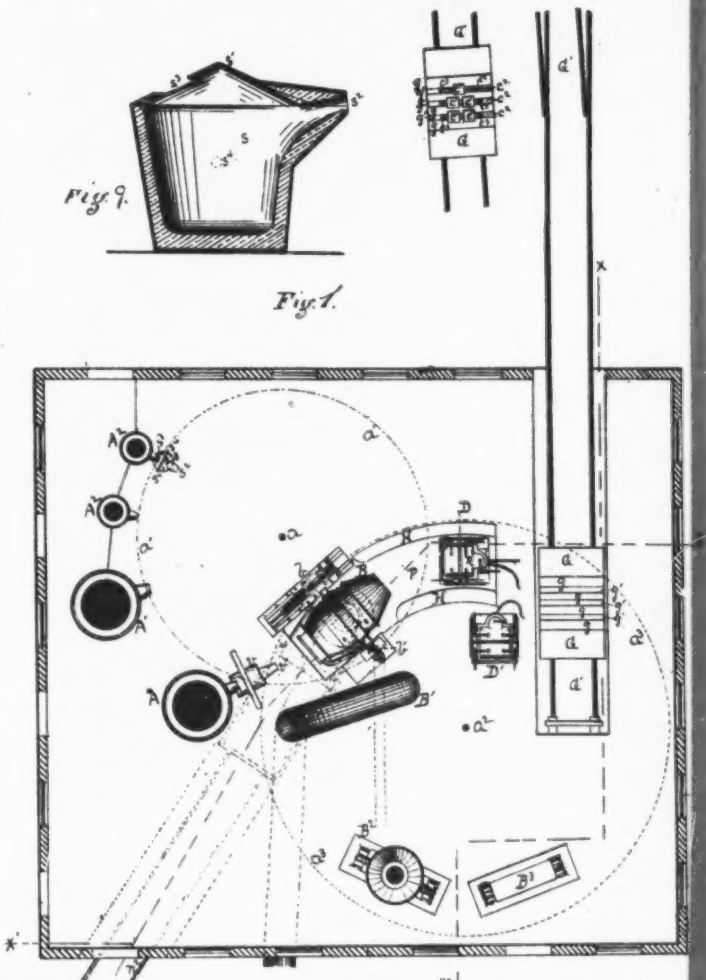
(No Model.) 4 Sheets—Sheet 1.

W. HAINSWORTH.

Bessemer Plant and Apparatus.

No. 238,110. Patented Feb. 22, 1881.

Carnegie Steel Co } p 1316
Cambria Iron Co }



Witnesses
R. H. Whitlesey
C. L. Parker

Inventor William Hainsworth,
By Attorney George H. Christy.

(No Model.) 4 Sheets—Sheet 2.

W. HAINSWORTH.

Bessemer Plant and Apparatus.

No. 238,110. Patented Feb. 22, 1881.

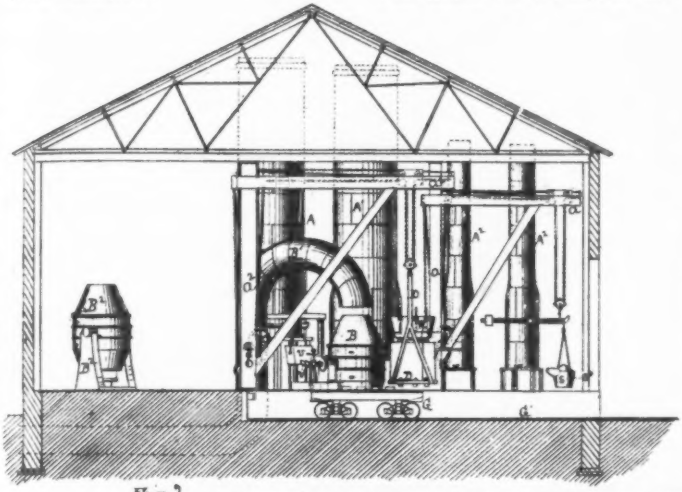
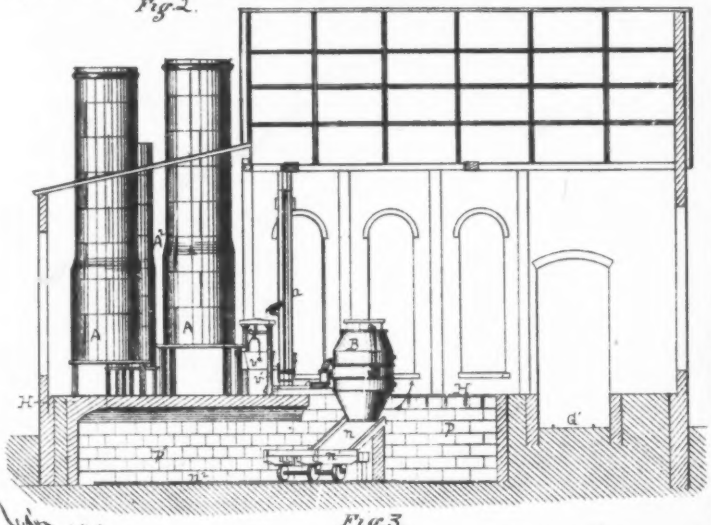


Fig. 2.



Witnesses:
R. F. Whitehead
C. L. Parker

Fig. 3.

Inventor: William Hainsworth
By Attorney: George N. Christy

(No Model.) 4 Sheets—Sheet 3.

W. HAINSWORTH.

Bessemer Plant and Apparatus.

No. 238,110. Patented Feb. 22, 1881.

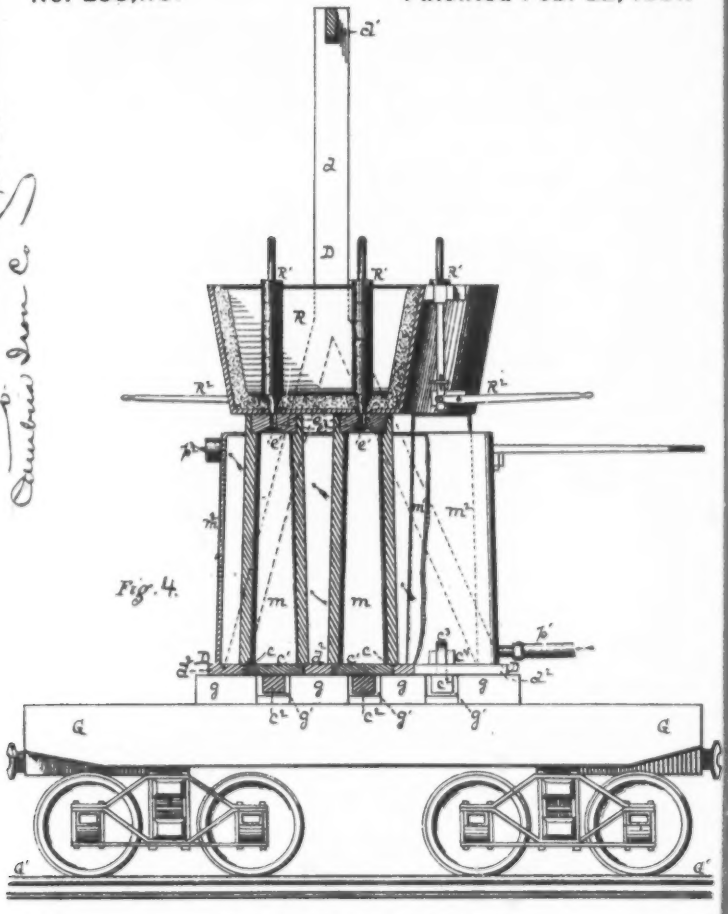


Fig. 4.

Fig. 5.

Witnesses
R. F. Whaley
C. L. Parker

Inventor William Hainsworth
By Attorney Geo. H. Christy

(No Model.) 4 Sheets—Sheet 4.

W. HAINSWORTH.

Bessemer Plant and Apparatus.

No. 238,110. Patented Feb. 22, 1881.

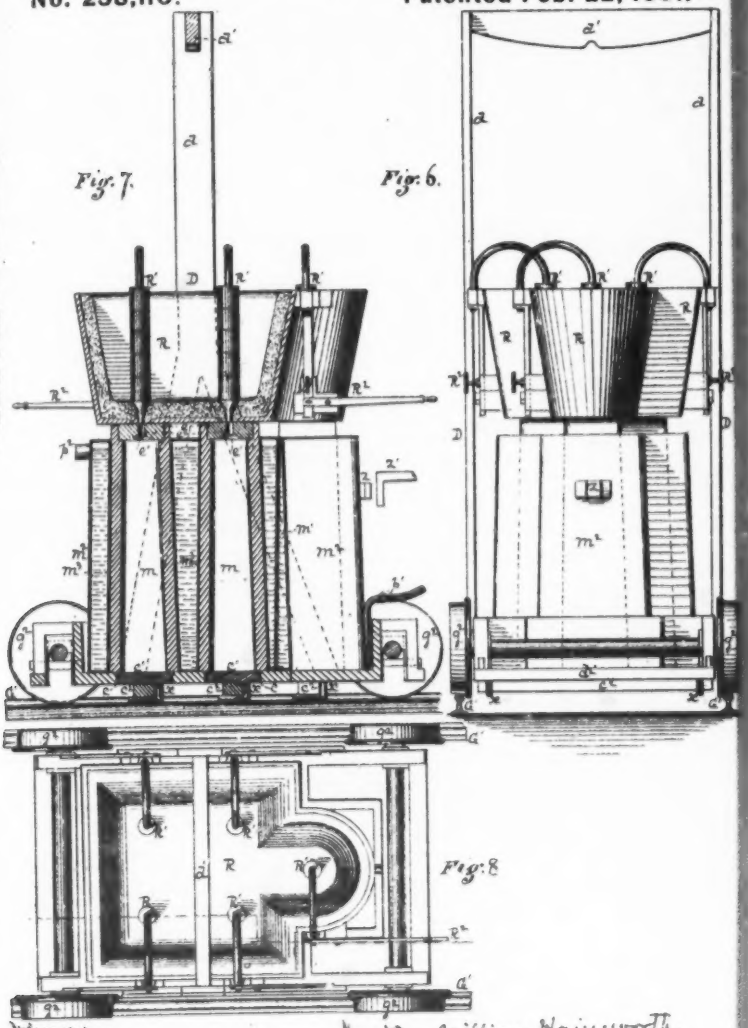


Fig. 7.

Fig. 6.

Fig. 8

Witnesses,
R. F. Osgood
A. L. Parker

Inventor William Hainsworth.
By his Attorney George H. Christy

the cover e is to provide an excess of metal in the axial line of the ingot, so that as the ingot solidifies and cools from the outside toward the center and shrinks from the center outwardly such excess of metal will compensate for such shrinkage, and give as a result a square-ended ingot, or one approximately so, and one which will, as a result thereof, work with less waste from "crop ends."

The ladle R is of the usual construction, except that, being made with a bottom large enough to cover and rest on all the covers e of the nest, it has a casting sprue or gate immediately over each cover-sprue, e^2, and in line therewith. The usual stoppers, R′, are added, and any suitable mechanism, R^2, for raising the stoppers.

I also consider it desirable to employ an air-blast or a water-jacket around the ingot-molds for the purpose of keeping their temperature down, as well as for the purpose of facilitating the solidification of the ingots. To this end (assuming, for the present, the use of an air-blast) I surround the nest of molds with a jacket, m^2, close at top and bottom, and provide a blast-inlet, p', and an outlet, p^2. By means of a suitable coupling a pipe from the air-blast apparatus can be coupled to and disconnected from the pipe p' at pleasure.

The cage with molds and ladle thereon is, when the charge in the converter is ready for pouring, swung by the crane a^2 into position over the pit P, and then is lowered into the pit and brought to a proper position therein, so that as the converter is rotated to the pouring position, it will discharge or pour into the ladle R. As soon as all the steel or good metal is poured out the cage is swung back, hoisted, and transferred onto a car, G, which can be run on a track, G′, to a point within the sweep of the crane. This car G, Figs. 1 and 3, is fitted up with bearings g, with intermediate recesses, g', so as to form a bearing-frame on which the cage may rest, the bars c^2 entering the recesses g', and the bottom plate, d^2, of the cage resting on the bearings g. The stoppers may then at once be withdrawn, or such withdrawal of the stoppers may be done as soon as the cage is raised to the ground or floor level, or while being transferred to the car, and the casting be done in the usual way. The four main molds m may all be filled at once or one at a time in succession, and if any metal is left after this is done it may be run into the fifth or extra mold, m'. As soon as the molds have solidified, the keys c^4 are knocked out, so as to loosen the bars c^2 and bottom blocks, c', and the cage is again hoisted by the crane, with the result of leaving the bars c^2 and the blocks c' resting on the car, and also of allowing the ingots to pass or drop out of the open bottoms of the molds. Then the car, with the ingots thereon, is run off to the bloomery or other place of working or storage on the track G′. The ingots may then be hoisted off the car. It will be observed that the bars c^2 and blocks c' still remain on the car and exactly or approximately in position to be again affixed to the cage, as illustrated in the plan view of the car on the upper part of sheet 1, where it will be understood that the track-rails on which the car stands is a section of the track G′, or of its siding, put to one side for convenience of illustration. The cage, as lifted off with its molds and ladle, is, as soon as lifted off, deposited on the ground or floor,

as at D', Fig. 1, for refitting or for being made ready for another pouring and casting operation; but during all this time another pouring and casting operation will have been done by the use of another cage, molds, ladle, and car, the duplicates of those already described. As one car is run off beyond the switch on one track, another is run up from the other track, and while one cage and its molds and ladle are being prepared for a new charge, another cage with molds and ladle is in use for receiving a charge and casting it into ingots in the manner described; and thus cars and cages alternate in use and the work goes on rapidly without exposing the workmen to any such dangers as are incident to pit casting; also, as all the manual labor is done on or above the level of the ground, it can be done under better and more favorable conditions as to light, ventilation, and cleanliness, and without trouble from a lack of room; also, as the ingots can be handled more expeditiously, they can be charged into a reheating-furnace while still retaining the greater part of their heat, so as to effect a saving in fuel and enable the work to go forward more rapidly, whereby from a given plant a greater output may be secured.

I also provide for getting rid of the waste, slag, or scoriæ left in the converter at the end of the pouring operation, whereby I avoid the danger incident to casting it in a button on the sand in the bottom of the pit. For this purpose I arrange a chute or spout, *n*, in the pit, Fig. 3, in proper position for receiving on its upper end the molten slag as soon as the converter is rotated beyond
1322 the point necessary in running off the good metal, and the slag running down such chute or spout is discharged into a sand-bed or into a suitable mold on the car *n'*, which latter is run off on a track, n^2, laid in a tunnel, P', to any desired point for dumping. At B^2 and B^3, Figs. 1 and 2, I have shown bearing-frames for one or more extra converters, with which to replace the one in use when it burns out or requires repairs, and on which such repairs can be made.

In the arrangement described I am enabled to locate the main cupola A quite near to the converter, so that as the metal is run from the cupola A into a ladle, *v*, and weighed, it may, by a short spout, *v'*, Fig. 1, be run directly into the converter-mouth, which, of course, is to be tilted over or back for the purpose. When necessary to take metal from the other cupola it may be run into a ladle, as before, and then swung, by crane *a*, to the head of the spout *v'*; but as the spiegel is liable to rapid oxidation if put into an open ladle or run any distance by a spout, I prefer to employ a ladle, *s*, (shown to an enlarged scale in Fig. 9), where it is represented as having a close top, *s'*, having only a small opening, as at s^3, through which to fill it from the tap-hole of the spiegel cupola, and having a pouring-spout, s^2, on the opposite side. This ladle is suspended from the crane *a* by trunnions s^4, with an interposed weighing apparatus, if so desired, and on being filled it may be swung around or run on a carriage and its contents poured directly into the converter-mouth, when the latter is tilted slightly forward, so as to experience little or no loss by oxidation. By thus avoiding

all occasion for the employment of manual labor in the pit I render it practicable to make the pit much deeper than is usual, and as a consequence I am enabled to lower the level of the platform or working stage H where most of the work is done. Hence I also lower correspondingly the converter and cupolas, so that all are at, or nearly down to, the level of the ground, whereby I effect a great saving in the cost usually incurred in elevating to a considerable height the large amount of material required in supplying and working a Bessemer converter. Also, all the appliances are so arranged that the carrying on of the necessary work and operations is greatly facilitated, so that from the beginning to the end of the operation the amount of manual labor required is greatly lessened, as well as its safety enhanced.

I have shown the cage, car, and casting apparatus in a somewhat modified form in Figs. 6 to 8 of sheet 4, where Fig. 6 is an end elevation; Fig. 7 is a vertical section, but partly in elevation; and Fig. 8, a top or plan view. Like letters in these figures represent the same as before. The only changes of importance are, that the truck-wheels g^2 are attached to or connected with the bed-plate d^2 of the cage, so as to be hoisted and moved therewith. After the casting is done, the cage, trucks, molds, ingots, and all are run off on the track G', Fig. 1, to any suitable place of unloading.

It will be observed that in this modification the bars c^2 are supported by hooks or open sided clips x. As soon as the apparatus reaches the place of discharging the ingots, either on a raised track or over a pit, the bars c^2 engage suitable knockers provided for the purpose, which force the bars out of their supports and let them with the blocks c' drop out of the way, whereupon the ingots drop through the bottom plate d^2, onto a chute leading to another car below, by which they are conveyed to the bloomery. The apparatus is duplicated, as before, so that the work may go on continuously. Also, instead of using an air-blast around the ingot-molds, I provide, in this case, for a water-jacket for the same purposes. The jacket m^2 has tubular connections m^3 from one end to the other, corresponding in number, size, form, and arrangement to the ingot molds, so as to make a tight water-casing entirely surrounding each mold. Water is supplied and discharged by like means and connections as the air. In the use of apparatus thus modified it may sometimes be desired to do the casting before the cage, &c., are shifted to the track, and while it is still swinging from the crane, as the casting of one ingot on one side of the nest might in such case tend to tip the cage too much for good work. I fasten a clip z, on the end of the cage or of the water-jacket case, so that a workman may insert the end of a lever, z', of any suitable length therein, and by the use of the lever prevent any objectionable tilting of the nest of ingots.

The means for opening and closing the holes through the bottom plate, d^2, of the cage for the purposes described, may be varied at pleasure, provided such holes be capable of being opened and closed from below in such manner as to provide for the discharge of the ingots through the bottom of the cage.

The object of supporting the ladle R partly or wholly on the mold-covers e is to hold the covers e securely in place, so that any lifting action which otherwise the fluid steel might have thereon as the mold becomes full is thereby prevented, and an ingot is secured having a well-formed upper end; and also greater uniformity in the sizes and shapes of the several ingots will be secured; and while the ingots may be cast one at a time, as already stated, I prefer to cast all at once by simultaneously (as nearly as practicable) raising all the stoppers at once, so that all shall be cast at the same temperature, or with the metal in the same condition.

In so far as the waste-pipe B′ may be usable for conveying heat to other points for useful purposes, no claim is made herein, but the same is reserved for the subject-matter of a separate application.

I claim herein as my invention—

1. An apparatus to be used in connection with a Bessemer plant for the pouring, casting, and removal of ingots, consisting
1323 of a cage adapted to be swung by a crane in one part of the operation, and to be run on a track in another part of the operation, said cage having holes in its bottom plate corresponding in size, number, and arrangement to the size, number, and arrangement of the nest of ingot-molds thereon, said holes being closed and opened from below for the removal of the ingots through the bottom of the cage, substantially as described.

2. In combination with a swinging cage having openings in its bottom closed and opened from below, a nest of ingot-molds arranged one over each such opening, and a ladle above and covering or extending over the entire nest of molds, and having a sprue or gate opening therefrom into the mold directly beneath it, substantially as set forth.

3. In combination with an ingot-mold, a cover, e, adapted to fit into and be supported in the mouth of the mold, made with a casting sprue or gate, e^2, directly through the same, and with a cavity, e', on its under side, substantially as set forth.

4. In combination with a nest of ingot-molds standing on a common level and of uniform height, and with a ladle extending over and covering the same, and provided with a sprue or gate over each mold, a cover, e, in each mold-mouth, centrally perforated and hollowing on its under side, and of suitable vertical height relative to the mold, for receiving and carrying some or all of the weight of the ladle, substantially as set forth.

5. In combination with a nest of molds arranged on a movable cage, a jacket surrounding such molds, and air or water supply and discharge pipes, for applying an air-blast or water-jacket to the molds, substantially as set forth.

6. A cage, D, carrying molds and ladles thereon, made with holes in its bottom plate for the downward discharge of the ingots from the molds, and supplied with blocks e', transverse bars e^2, and suitable fastenings for securing such bars to the cage, in combination with the bearings and recesses g g' of a car-platform, arranged substantially as set forth, whereby, when the cage is seated on the

car and the fastenings are loosened, the cage may be lifted off and the ingots removed, while leaving the blocks and bars in the proper position to be attached to the same or to another like cage, substantially as set forth.

7. In a Bessemer plant, the construction, for conjoint operation, of a system of apparatus consisting of a rotary converter, a pit, P, of proper size and depth for the swinging under the mouth of the converter, when in a pouring position, of a cage carrying a nest of ingot-molds and a ladle thereon, a crane for lowering and swinging the cage into position under the pouring-mouth, and for swinging it away, raising it out of the pit, and transferring it onto a track arranged within the sweep of the crane, substantially as set forth.

8. An improved ladle, s, having side trunnions, s^2, a close top, s', a filling-opening, s^3, and a pouring-spout, s^4, substantially as set forth.

9. The swing-pipe B′, in combination with converter B, substantially as set forth.

In testimony whereof I have hereunto set my hand.

WILLIAM HAINSWORTH.

Witnesses:

R. H. WHITTLESEY.

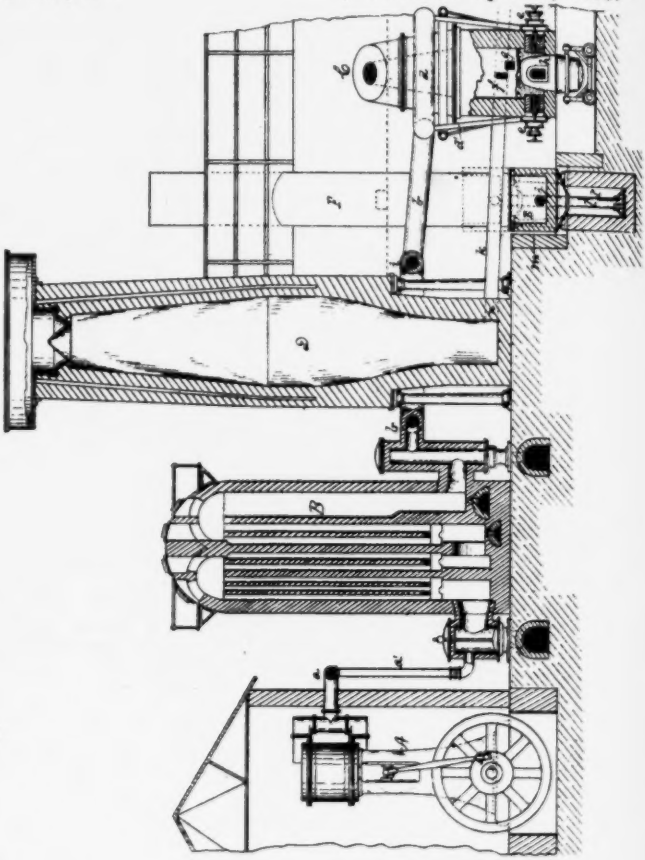
GEORGE H. CHRISTY.

(No Model.)

J. P. WITHEROW.

APPARATUS FOR THE MANUFACTURE OF IRON AND STEEL.

No. 315,587. Patented Apr. 14, 1885.



Carnegie Steel Co. v. Cambria Iron Co. } p 134

Witnesses

W. B. Corwin

Jno. K. Smith

Inventor

James P. Witherow

by his attys

Bakewell & Kear

1325 UNITED STATES PATENT OFFICE.

JAMES P. WITHEROW, of Allegheny, Pennsylvania.

Apparatus for the Manufacture of Iron and Steel.

Specification forming part of Letters Patent No. 315,587, dated April 14, 1885. Application filed January 16, 1884. (No model.)

To all whom it may concern:

Be it known that I, James Porter Witherow, of Allegheny city, in the county of Allegheny and State of Pennsylvania, have invented a new and useful improvement in apparatus for the manufacture of iron and steel; and I do hereby declare the following to be a full, clear, and exact description thereof.

The object of my invention is to facilitate and cheapen the conversion of crude cast-iron into ingot iron or steel by the Bessemer or pneumatic process. For this purpose I so combine the blast furnace in which the iron is produced or melted with the converter and other appliances used by me as to utilize the blast forcing and heating apparatus of the furnace for converting purposes and make the production of steel from the ore a continuous operation in a single plant.

To enable others skilled in the art to make and use my invention, I will now describe it by reference to the accompanying drawing, which is a view, partly in section, of a plant embodying my invention.

(Here follows diagram marked p. 1324.)

Here A indicates a blowing-engine of any suitable construction, for the purpose of pumping and forcing atmospheric air into the converter to effect the operations and reactions therein. B indicates a Whitwell fire-brick or superheating stove, to which the blast passes from the engine by pipes *a a'*, and in which the air may be heated. C indicates a fixed converter having a blast-main, *d*, blast-pipes *d'*, tuyeres *e*, charging-hole *f*, a slag-metal tapping-hole, *g*, situated at or slightly above the metal-line, and a tapping-hole, *h*. The blast-trunk *d* is connected with the heating-stove B by pipes *b*.

My invention is applicable without change and with great economy to existing blast-furnace plants. Such an application utilizes the blowing-engines and blast-heating stoves of the plant, and consequently saves the expense of constructing separate ones for the converter, and at the same time does not interfere with usual and ordinary operation of the blast-furnace. It also saves the cost of a cupola for melting the metal to be charged into the converter, for it brings the latter near to the blast-furnace, so that it can be charged directly therefrom.

In the drawing, D indicates an ordinary blast-furnace, which in this instance would be used in making suitable pig. It is prefer-

ably placed between the stove B and converter C, and is provided with a blast-trunk, i', of the usual construction. The pipe b, which leads to the wind-main d of the converter, is connected to the blast-main i' and receives the blast therefrom.

Extending from the blast-furnace D to the charging-hole g of the converter is a charging-spout, k, of the usual construction. This spout enables the converter C to be charged from time to time directly from the blast-furnace. As, however, it is often undesirable to tap the metal from the blast-furnace every time the converter, which is relatively very much smaller than the blast-furnace, is charged, I have provided a vessel or receptacle, E, having a tap-hole, j, capable of holding any desired quantity of metal. It is preferably constructed to take the whole amount of a cast from the blast-furnace, but may be made for or used with a smaller quantity. It may be mounted on the piston l of a hydraulic cylinder, l', placed in the bottom of a pit, m, made in the floor of the casting-house, whereby the vessel can be raised out of or lowered into the pit, which is constructed of fire-brick, and is designed to inclose the vessel and maintain the heat of the metal, so as to keep it as long as necessary in the proper molten condition for tapping off into the converters, of which there may be several. The mouth of the vessel E, when it is sunk in the pit m, is on a level with or slightly below the metal-tap hole n of the blast-furnace, so that the molten metal can be tapped directly from the blast furnace into it. It may, if desired, be dropped below the level of the floor when filled, and the top of the pit closed by a suitable door or cover.

When it is desired to charge the crucible C, the vessel E is raised to the charging-spout k, as indicated by broken lines, the stopper withdrawn from the tap-hole j, and the requisite quantity of metal permitted to flow into the crucible C. Thus the vessel E constitutes an intermediate distributing-reservoir for the metal after its withdrawal from the blast-furnace, the use of which obviates the
1326 necessity of interfering with the regular and uniform operation of the blast-furnace by the frequent tapping off of the relatively small quantity of metal necessary to charge the converter or converters, the time required for the operation in the latter being so short that they need to be charged several times between each regular tapping of the blast-furnace. The intermediate vessel, E, may, if desired, be used in connection with a cupola, F, in which case its operation would be the same as has just been described.

The use of the hot or superheated blast is of great advantage in case the molten metal in the converter becomes too cold for its proper treatment therein, as in case scrap is charged, or the heat-producing elements are exhausted, or nearly so, for the heat imported by the blast so increases its calorific power as to enable it to restore the metal to its proper condition of fluidity. Thus much of the danger of the metal's chilling in the converter is taken away. It also augments and intensifies the reactions in the converter, shortening the blow, and aids in the dissociation of the impurities, which may be tapped off during the blow.

What I claim as my invention, and desire to secure by letters patent, is—

1. The combination of a blast-furnace, a blast-heating stove, a converting-vessel, an intermediate distributing-receptacle, and connections for the blast and transfer of the metal, substantially as and for the purposes described.

2. The combination of a blast-furnace with a converter having side tuyeres, and a cinder-tap at or near the metal-line, substantially as and for the purposes described.

3. The combination of a blast-furnace and converter, blast connections extending from the blast-furnace to the converter, and tuyeres provided with stoppers to control the blast at the converter, substantially as and for the purposes described.

In testimony whereof I have hereunto set my hand this 4th day of January, A. D. 1884.

JAMES P. WITHEROW.

Witnesses:
W. B. CORWIN.
THOMAS B. KERR.

1329 UNITED STATES PATENT OFFICE.

JAMES P. WITHEROW, of Allegheny city, Pennsylvania.

Steel-plant Appliance.

Specification forming part of Letters Patent No. 327,425, dated September 29, 1885. Application filed July 8, 1885. (No model.)

To all whom it may concern:

Be it known that I, James P. Witherow, of Allegheny city, in the county of Allegheny and State of Pennsylvania, have invented a new and useful improvement in steel-plant appliances; and I do hereby declare the following to be a full, clear, and exact description thereof:

In the manufacture of steel by the pneumatic process the converters are charged with molten metal, the product of the blast-furnace. This metal is usually cast in the form of pigs, and then remelted in a cupola as needed before being charged into the converter. The metal is usually tapped from a blast-furnace once in every six hours, and the quantity thus cast is many times in excess of the charge of a converter. Economy of manufacture forbids more frequent casting, and particularly the casting of the comparatively small quantity necessary for a converter-charge, and with the frequency required therefor, the periods of the operations of which are comparatively much shorter than those of the blast-furnace. It is very desirable to take advantage of the molten condition of the metal as it comes from the blast-furnace for its use in the converter, because thereby the remelting of the metal and the expense of the construction of a cupola may be avoided. The charge of a converter is from one to five tons, and the cast of a blast-furnace runs usually from ten to fifty tons. The difficulty of using the molten metal from the furnace in the converter consists in keeping the large quantity of metal from the latter in a proper molten condition for use in the former. The time between charges of the converter is usually twenty minutes and upward, and the metal from the furnace must be kept in condition to be tapped from time to time into the converter as needed. This is the object of my invention, to explain which, so that others skilled in the art may make and use the same, I will now refer to the accompanying drawings, in which—

(Here follow diagrams marked pp. 1327 & 1328.)

Figure 1 is an elevation of a blast-furnace and a vertical section of a receiving-receptacle and distributing-ladle. Fig. 2 is a sectional plan view of the same. Figs. 3, 4, and 5 are views of the receiving-receptacle.

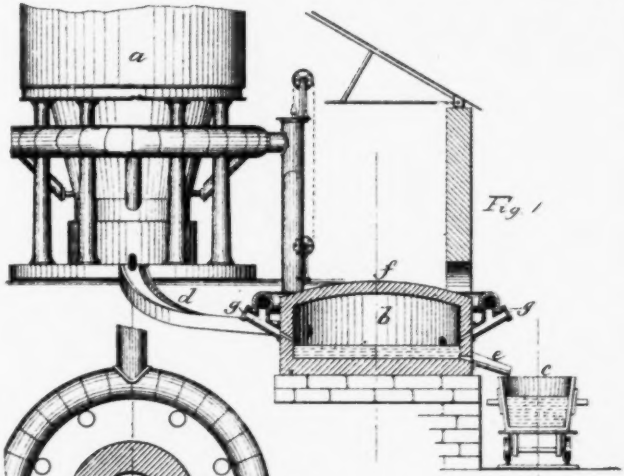
The blast-furnace *a* is used to reduce the iron from its ores in the ordinary way.

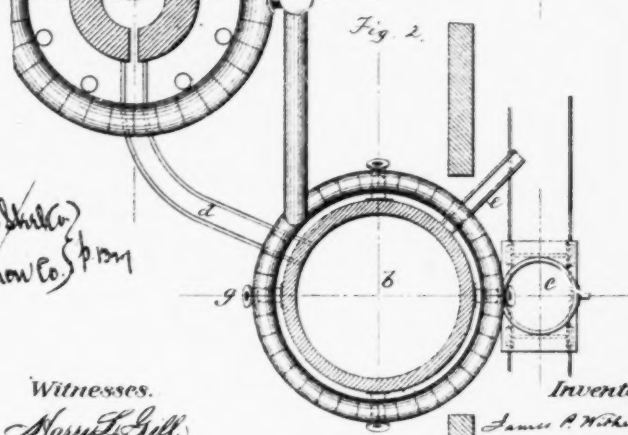
(No Model.) 2 Sheets—Sheet 1.

J. P. WITHEROW.

STEEL PLANT APPLIANCE.

No. 327,425. Patented Sept. 29, 1885.





Carnegie Steel Co. v. Cambria Iron Co. Exhibit

Witnesses.
Harry L. Gill
W. B. Corwin

Inventor.
James P. Witherow
by his attys
Bakewell & Kerr

(No Model.) 2 Sheets—Sheet 2.

J. P. WITHEROW.

STEEL PLANT APPLIANCE.

No. 327,425. Patented Sept. 29, 1885.

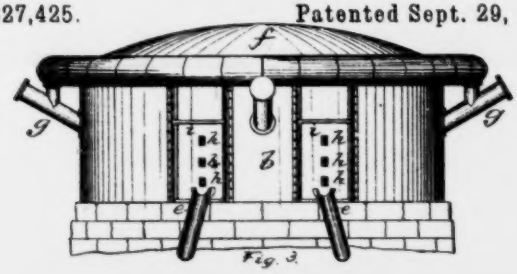
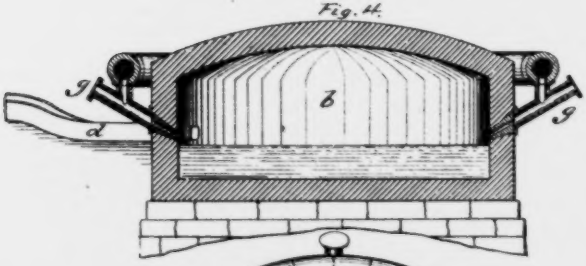


Fig. 3.

Fig. 4.



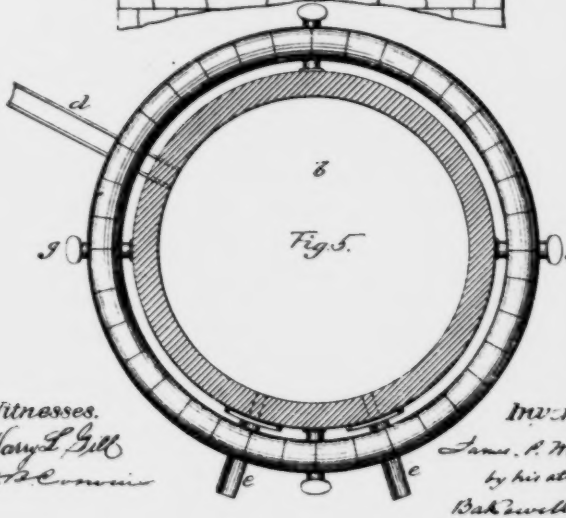


Fig. 5.

Carnegie Steel Co. } p. 1328
Cambria Iron Co. }

Witnesses.
Harry L. Gill
W. B. Corwin

Inventor.
James P. Witherow
by his attys
Bakewell & Kerr

The receptacle *b* is designed to receive and hold the entire cast of the furnace *a*, being of a sufficient size for that purpose.

The ladle *c* is designed to receive and convey to the converter or converters (not shown) a proper charge or charges of the metal from the receptacle *b*.

Suitable troughs, *d* and *e*, are provided between the furnace *a* and receptacle *b* and between the latter and the ladle *c*, to conduct the molten metal from one to the other. The receptacle *b* is provided with a suitable cover, *f*, and with tuyeres *g*, which blow down upon the surface of the metal for the purpose of maintaining its heat and fluidity. I prefer to use hot or cold air or gas for this purpose. When natural gas is accessible, it may be used; but it should not be blown below the surface of the metal. The effect of the blast of air is to produce an agitation of the bath, accompanied with more or less oxidation of the metal and the production of a base, which, uniting with the silicic acid, forms a slag on the surface of the bath. This covering of slag serves to protect the metal from excessive oxidation, and reduces the loss of temperature by radiation. The receptacle is also provided with a series of tapping-holes, *h*, arranged at different heights in its sides. The holes are preferably made in a vertical cast-iron stave, *i*, and when the vessel is in use are stopped with clay. In tapping, the clay stopper of the proper hole is punctured, and the metal permitted to run out.

The tapping-holes may be arranged as to relative height with reference to the capacity of the vessel, so that the opening of any particular hole will insure the delivery of a determined quantity of metal. In this way the use of a weighing-ladle or other means of determining the charge of the converter may be rendered unnecessary.

If it is desired to tap off the slag it may be done by opening the proper tapping-hole *h*.

I do not limit myself to the use of several tuyeres in connection with the receptacle *b*, nor to placing the tuyeres in the side of the vessel, but desire also to include the use of one tuyere, while the tuyere or tuyeres may be inserted from the top or from the bottom, if desired, and may be fixed or movable, as preferred.

The amount and pressure of the blast in the tuyere or
1330 tuyeres will be regulated to suit the purpose for which it is supplied and the quantity of metal present.

What I claim as my invention, and desire to secure by letters patent, is—

1. The combination of a blast-furnace with a storage-receptacle provided with tuyeres for receiving and holding the fluid cast of the furnace, a distributing-ladle, and conducting-spouts for transferring the metal from one to another, substantially as and for the purposes described.

2. A storage-receptacle for containing and dispensing fluid metal provided with a tuyere or tuyeres for supplying a blast of air or gas to maintain the metal in a fluid condition and a suitable tapping-hole, substantially as and for the purposes described.

3. A storage-receptecle for containing and dispensing fluid metal

provided with a tuyere or tuyeres for supplying a blast of air or gas to maintain the temperature of the metal and a series of metal tapping-holes arranged at different heights in the sides of the same, substantially as and for the purposes described.

In testimony whereof I have hereunto set my hand this 30th day of June, A. D. 1885.

JAMES P. WITHEROW.

Witnesses:
THOMAS B. KERR.
W. B. CORWIN.

1331 [British coat of arms.]

A. D. 1856. No. 44.

Manufacture of Iron and Steel.

Letters patent to Henry Bessemer, of Queen Street place, New Cannon street, in the city of London, for the invention of "improvements in the manufacture of iron and steel."

Sealed the 24th June, 1856, and dated the 4th January, 1856.

Provisional specification left by the said Henry Bessemer at the office of the commissioners of patents, with his petition, on the 4th January, 1856.

I, Henry Bessemer, of Queen Street place, New Cannon street, in the city of London, do hereby declare the nature of the invention for "improvements in the manufacture of iron and steel" to be as follows:

In the process of refining iron as generally practised in Great Britain, a "finery or running-out furnace" is used, in which the pig iron is placed upon a heap of coke which occupies the hearth of the furnace; more coke is then laid upon the iron, and a powerful blast is kept up until the metal is melted, and has run down into the hearth, and displaced the coke which at the commencement of the process occupied that part of the furnace; the melted iron will then present only its upper surface to the action of the fire, while the bottom and sides of the hearth will absorb a portion of the heat from the metal; at the same time the decarbonization of the iron which is going on will render it less easily fusible; hence it follows, that the complete decarbonization of the metal cannot be effected in such furnaces, in consequence of the insufficient degree of
1332 heat applied to the surface of the metal, which would in consequence become solidified. It has therefore been the general practice only to partially refine the metal in such furnaces, and to complete its refinement by the process of puddling in a furnace peculiarly adapted for such purpose, and in which process the iron passes from the fluid to the pasty or solid state.

Now, the object of my present invention is the more perfect and complete refinement of the iron, whereby it gradually loses the properties common to pig or crude iron, and acquires the properties of cast steel, or of pure or decarbonized iron, while it still preserves such a state of fluidity as will admit of its being cast into ingots or other desired forms or articles, by the process of founding. For which purpose I expose the iron in a more divided or extended form to the intense heat of the furnace or furnaces hereinafter described, and to the oxydizing action of a blast of air, by keeping such fluid metal in motion, and continually bringing fresh portions of it in contact with oxygen, and with the intensely ignited fuel, or

with the highly heated interior surface of the furnace, the metal being thus kept in a fluid state until the desired amount of decarbonization or refinement is arrived at. The iron to be used for the purposes of my present invention may be conveyed by a gutter in a fluid state direct from the smelting furnace where it has been obtained from the ore, and be allowed to flow into the improved furnace or furnaces hereinafter described, or it may be obtained from any convenient form of remelting furnace, or the iron may undergo a previous partial refinement in the old or any other convenient way; and which iron I proceed to complete the refinement of in any one of the following modifications of apparatus:

The first and most simple arrangement consists of a series of small cupola or blast furnaces, so placed in reference to each other on a series of steps that the fluid metal may flow from one to the other. An arch or slab of fireclay in the upper part of each furnace will receive the stream of fluid iron as it flows from the bottom of the upper furnace into the top of the furnace immediately below it; the metal will by this means be scattered, and fall in a shower through the highly heated fuel, and through the blast of air which finds its way in an upward direction through it: the fluid iron will thus pass in succession through several different furnaces, and collecting in the bottom one, may be tapped from it as required.

A second modification of my improved apparatus consists of two cupola or blast furnaces, placed side by side and very close to each other; beneath each furnace I place a strong iron tube or cylinder, into which I fit a plunger or ram, similar to a hydraulic press; upon the head of each ram I construct the furnace, so that by a suitable pump each of the furnaces may in succession be
1333 raised above the level of the other; the upper one being then made to distribute the fluid metal contained therein into the lower one, the metal falling in a shower and passing down among the fuel, and in this divided state offering a considerable amount of surface to the decarbonizing action of the blast of air passing upwards through the furnace, the alternate raising and lowering of the two furnaces admitting of a continuation of the process for any required length of time. The blast pipe attached to each furnace must be made to slide vertically in and out of a fixed piece of pipe, so that the blast may be kept up notwithstanding the movement of the furnaces; there must also be formed on the said furnaces suitable spouts for the discharge of the metal, both for the supply of each other, and for the final discharge of the metal into the mould after its refinement is completed.

The third arrangement of apparatus which may be used for carrying into effect my said invention, consists in forming a furnace of a cylindrical or spherical form, the outside shell being composed of boiler plate lined internally with firebricks coated with loam; the furnace is to be mounted on hollow horizontal axes which are mounted in a suitable frame, so that rotary motion may be communicated to the furnace. On the interior I form several shelves or ribs, for the purpose of lifting up the fluid metal and letting it fall again through the fuel, and so on continuously until the refinement

of the iron is effected. It will be observed that those parts of the furnace which at one part of its revolution form the roof, and are exposed to the intense heat of the fuel, will at another part of its revolution form the bed on which the chief portion of the metal rests; and hence, instead of their being a continual loss of heat from the metal, from its absor-tion by the bed of the furnace, there will be a constant accession of heat to the metal, by the highly heated *interior surface of the furnace descending below the fluid* metal, and forming for the time the bed on which the metal rests. In some cases the shelves may be dispensed with, which will allow the metal quietly to slide over the highly heated surface of the interior of the furnace, the fuel floating on the surface of the metal. In either case it will be understood that the axes of the furnace will be made hollow, and of such a diameter as to admit the blast pipe at one end, while the opposite one is made large enough to admit the fuel and metal, and at the same time serve as a means for the products of combustion to escape. Although the horizontal revolving furnace herein lastly described has the advantage of always presenting a newly heated surface for the metal to rest on, it nevertheless does not present so large a surface of fluid iron to the action of the fire, and to the decarbonizing action of the blast, as may be obtained by causing the furnace to revolve on a vertical axis
1334 in the manner hereinafter described; and which modification of furnace I prefer for the purpose of refining iron until so much of its carbon has been driven off as to give to the said crude iron the properties of, or to convert it into, steel, or pure or nearly pure refined iron. And here I would observe, that for ordinary purposes coke may be used for fuel for carrying into effect my said invention, although I in all cases where the quality of the metal is of great importance prefer to use charcoal, wood, or prepared peat, as the effects of such last-named fuels are less injurious to the metal than coke made from mineral coal.

In constructing furnaces to revolve on a vertical axis, the cylindrical form is most suitable; the outside shell (being made of strong boiler plate soundly riveted) is to be lined with firebrick and coated with loam, the upper part being closed partly over, leaving a central hole at the top, of about one-third the diameter of the furnace; the bottom of the furnace is formed of cast iron, strongly ribbed and keyed onto a spindle; the foot of this spindle rests in a footstep sunk several feet below the ground level, the upper part of the spindle working in a bearing formed in an iron frame secured to heavy masonry; this spindle has keyed upon it a wheel, by which a rapid rotary motion is given to it. A fire having been made in the furnace, and a powerful blast applied to it, either through the centre of the furnace at bottom, or by nozzles at the sides, which communicate with a hollow space around the axis; when the interior of the furnace is brought up to an intense heat, the fluid iron may be run into it, and a rapid motion communicated to the furnace, whereby the fluid metal will rise up the sides of it as far as where the top closes over, and be there suspended by centrifugal force, the metal being distributed in a cylindrical layer of a few

inches only in thickness; the fuel and heated vapours will by the same agency be pressed continually in contact with the fluid metal, and act powerfully thereon. By diminishing and increasing alternately the speed of the furnace, the metal will rise up or sink lower down in the furnace, and thus afford constantly fresh surfaces to the action of the fire and oxygen present in the furnace, which, by combining with the carbon contained in the iron, will refine and purify it to the required extent. In some cases, however, I find it preferable to introduce a fireclay pipe into the fluid metal in the bottom of the furnace, and by means of it force a current of hot air into and among the fluid metal; when the metal is somewhat cooled, the pipe may be withdrawn, and the motion of the furnace continued until it has been again heated up, when the process of blowing air or steam through the fluid metal may be repeated; and here I would remark that hot or cold air may be used, but I prefer hot blast, and that it should be heated to the highest practicable limit. As soon as the complete refinement of the
1335 metal is effected, the motion of the furnace may be discontinued, and the fluid steel or iron be tapped out of the side of the furnace as usually practised in cupola furnaces used for melting iron, the metal so run out being received into suitable ingot moulds, whereby blocks of metal will be formed, suitable for hammering or rolling into bars, plates, rails, or rods, and which may be either hard steel, soft steel, hard iron, or soft iron, according to the extent of the refining process. And here I would observe, that when I desire to make steel of a superior quality, I carry out the refinement of crude iron as far as possible, and produce thereby soft iron, which I cast while in a fluid state into ingots, which I afterwards roll into bars or rods of the desired form and size; the iron bars thus formed, I cement with charcoal in the manner already practised in making blister steel; but the cemented bars made from cast ingots of iron will not form blisters, in consequence of their freedom from iron scales. When the process of cementation has been carried to the desired extent, the bars are removed from the cementing chest, and again rolled or tilted, as already practised in the manufacture of steel.

Specification in pursuance of the conditions of the letters patent filed by the said Henry Bessemer in the Great Seal patent office on the 4th July, 1856.

To all to whom these presents shall come I, Henry Bessemer, of Queen Street place, New Cannon street, in the city of London, send greeting:

Whereas Her Most Excellent Majesty Queen Victoria, by her letters patent, bearing date the fourth day of January, in the year of our Lord one thousand eight hundred and fifty-six, in the nineteenth year of her reign, did, for herself, her heirs and successors, give and grant unto me, the said Henry Bessemer, her special licence that I, the said Henry Bessemer, my executors, administrators, and assigns, or such others as I, the said Henry Bessemer, my

executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel islands, and isle of Man, an invention for "improvements in the manufacture of iron and steel," upon the condition (amongst others) that I, the said Henry Bessemer, my executors or administrators, by an instrument in writing under my, or
1336 their, or one of their hands and seals, should particularly describe and ascertain the nature of the said invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal patent office within six calendar months next and immediately after the date of the said letters patent.

Now, know ye, that I, the said Henry Bessemer, do hereby declare the nature of the said invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement thereof, that is to say:

In the process of refining iron as generally practised in Great Britain, a "finery or running-out furnace" is used, in which the pig iron is placed upon a heap of coke which occupies the hearth of the furnace; more coke is then laid upon the iron, and a powerful blast is kept up until the metal is melted and has run down into the hearth, and displaced the coke which at the commencement of the process occupied that part of the furnace; the melted iron will then present only its upper surface to the action of the fire, while the bottom and sides of the hearth will absorb a portion of the heat from the metal: at the same time the decarbonization of the iron which is going on will render it less easily fusible; hence it follows that the complete decarbonization of the metal cannot be effected in such furnaces, in consequence of the insufficient degree of heat applied to the surface of the metal, which would in consequence become solified. It has therefore been the general practice only to partially refine the metal in such furnaces, and to complete its refinement by the process of puddling in a furnace peculiarly adapted for such purpose, and in which process the iron passes from the fluid to the pasty or solid state.

Now, the object of my present invention is the more perfect and complete refinement of the iron, whereby it gradually loses the properties common to pig or crude iron, and acquires the properties of cast steel, or of pure or decarbonized iron, while it still preserves such a state of fluidity as will admit of its being cast into ingots or other desired forms or articles, by the process of founding. For which purpose I expose the iron in a more divided or extended form to the intense heat of the furnace or furnaces hereinafter described, and to the oxydising action of a blast of air, by keeping such fluid metal in motion, and continually bringing fresh portions of it in contact with oxygen, and with the intensely ignited fuel, or with the highly heated interior surface of the furnace, the metal being thus kept in a fluid state until the desired amount of decarbonization or refinement is arrived at.

The iron to be used for the purposes of my present invention

may be conveyed by a gutter in a fluid state direct from the
1337 smelting furnace, where it has been obtained from the ore, and be allowed to flow into the improved furnace or furnaces hereinafter described, or it may be obtained from any convenient form of remelting furnace, or the iron may undergo a previous partial refinement in the old or any other convenient way; and which iron I proceed to complete the refinement of in any one of the following modifications of apparatus.

The first and most simple arrangement consists of a series of small cupola or blast furnaces, so placed in reference to each other on a series of steps, that the fluid metal may flow from one to the other. An arch or slab of fire clay in the upper part of each furnace will receive the stream of fluid iron as it flows from the bottom of the upper furnace into the top of the furnace immediately below it, or the metal may be allowed to flow on to the fuel; in either case the metal will by this means be scattered, and fall in a shower through the highly heated fuel, and through the blast of air which finds its way in an upward direction through it; the fluid iron will thus pass in succession through several different furnaces, and collecting in the bottom one, may be tapped from it as required." The cupola furnaces used in carrying out this part of my present invention may be constructed precisely similar to those at present in general use by iron founders, and may be supplied with a blast of air also in a similar manner, the tap hole of each furnace in the series being left open so as to allow the metal to flow out as fast as it accumulates in the lower part of the furnace, or the tap holes may be stopped with loam in the usual way, and the metal be retained therein, until the whole or a greater part of it is accumulated previous to allowing it to flow into the next furnace of the series, the lower one in all cases having its tap hole stopped, so that all the metal may be there collected and be afterwards run into ingot or other moulds, as desired."

"A second modification of my improved apparatus consists of two cupola or blast furnaces placed side by side and very close to each other; beneath each furnace I place a strong iron tube or cylinder, into which I fit a plunger or ram, similar to a hydraulic press; upon the head of each ram I construct the furnace, so that by a suitable pump each of the furnaces may in succession be raised above the level of the other; the upper one being then made to distribute the fluid metal contained therein into the lower one, the metal falling in a shower and passing down among the fuel, and in this divided state offering a considerable amount of surface to the decarbonizing action of the blast of air passing upwards through the furnace, the alternate raising and lowering of the two furnaces admitting of a continuation of the process for any required length of time. The blast pipe attached to each furnace must be made
1338 to slide vertically in and out of a fixed piece of pipe, so that the blast may be kept up notwithstanding the movement of the furnaces; there must also be formed on the said furnaces suitable spouts for the discharge of the metal, both for the supply of

FOLDOUT(S) IS/ARE TOO LARGE TO BE FILMED

each other and for the final discharge of the metal into the mould after its refinement is completed."

In order that this modification of my invention may be fully understood I have hereunto annexed a sheet of drawings, marked A, on which I have represented at figure 4 a pair of cupola or blast furnaces, one of which is shown in elevation, and the other in vertical section.

(Here follows diagram marked p. 1349.)

a is a cupola or blast furnace of the usual construction; it is fixed on the head *b** of a hydraulic ram *b;* the ram is accurately fitted to the upper part of the cylinder *c*, so as to keep it steady, and is kept water-tight by a leather ring at *d*, as commonly used in hydraulic presses. The cylinder *c* has a large flange *c** at its upper end, which rests on the foundation plate *e;* at *f* is shewn another cupola or blast furnace in section; it is in all respects similar to the one already described; it is supported on a ram *g*, which works in a cylinder *h*. Hot or cold blast is supplied to these furnaces from the main pipe *i*, having elbows *m*, which turn upwards and are joined to the bed plate *e;* resting on the bed plate are two cylinders *r*, of cast iron, the tops of them being fitted with stuffing boxes, so as to enable the tuyere pipes *s* to slide in and out of them freely, but without loss of air.

The action of the apparatus is as follows: A fire being lighted in both furnaces, the blast is to be applied until the fuel is well burned up, and the interior of them brought up to a very high temperature; after which a charge of fluid iron from the smelting furnace may be run into the furnace *a*, or pig iron may be put in with the fuel, as is usually practised in smelting iron for foundry purposes. In either case, the iron having collected in the bottom of the furnace, a two-way cock (not shewn in the drawings) is to be opened, so as to admit water from an elevated reservoir to flow into the cylinder *c* by the pipe *t;* the effect of which will be to raise the ram *b* and furnace *a* into the position shewn in the drawings. A workman standing on a suitable platform (not shewn in the drawings) will open the tap hole of the furnace *a*, when the metal will flow out, as shewn, at *u*, and falling on to the fuel in the furnace *f*, will be divided into numerous globules, and descend among the fuel in a sort of shower, meeting in its descent the blast of air which is always forcing its way upwards among the fuel from the tuyere *s**, and thus a partial decarbonization of the metal will be effected. As soon as the whole charge has accumulated in the furnace *f*, the two-way cock, before referred to, is to be reversed, whereby the water from
1339 the elevated reservoir will enter the cylinder *h* by the pipe *v*, and raise up the ram *g* and furnace *f*, while the water will leave the cylinder *c*, and allow the ram *b* and furnace *a* to be lowered down; the workman will then plug the tap hole of the furnace *a* and open that of the furnace *f*, so that the metal may fall as a shower among the incandescent fuel in the furnace *a*, and thus acquire an additional temperature, accompanied with a further

decarbonization of the metal, and thus the alternate action of the two furnaces may be kept up until the desired amount of decarbonization or refinement is obtained; after which the fluid metal may be run from the tap hole into a ladle, and be then poured into ingot or other molds; or the fluid metal may be run into the moulds direct from the furnace. The workman who conducts the operation should make small sample ingots as the process proceeds, so as to enable him to judge of the state of the metal, which may be made into hard or soft steel, or into steely or soft malleable iron, according as the quantity of carbon originally combined with the crude iron is reduced by the action of the blast of air which is passing upwards through the furnace.

In either of the modifications of apparatus herein described, hot or cold air may be employed, and it should always be used in excess of the quantity required for the combustion of the fuel, in order that the gaseous matters in the furnaces may contain enough oxygen to act upon the metal. Charcoal, wood, or coke may be used separately or mixed as fuel, and the refinement and purification of the metal may be assisted, if desired, by the use of salt, oxide of manganese, iron scales, or other matters that have hitherto been employed for such purposes in the process of puddling iron.

I have before remarked that a portion of the heat of the finery and running-out furnaces now employed is lost by the conducting power of the sides and bottom of the hearth; at the same time that the fluid metal does not present a sufficient amount of surface to the ignited fuel to allow of its being converted into steel or malleable iron while still retaining a fluid state, as in the apparatus hereinbefore described; and also in the third arrangement of apparatus, which may be used for carrying into effect my said invention, and which consists in forming a furnace of a cylindrical or spherical form, the outside shell being composed of boiler plate, lined internally with fire bricks coated with loam; the furnace is to be mounted on hollow horizontal axes, which are mounted in a suitable frame, so that rotary motion may be communicated to the furnace. In the interior I form several shelves or ribs, for the purpose of lifting up the fluid metal and letting it fall again through the fuel, and so on continuously, until the refinement of the iron is effected. It will be observed that those parts of the furnace
1340 which at one part of its revolution form the roof, and are exposed to the intense heat of the fuel, will at another part of the revolution form the bed on which the chief portion of the metal rests; and hence, instead of there being a continual loss of heat from the metal, from its absorption by the bed of the furnace, there will be a constant accession of heat to the metal by the highly heated interior surface of the furnace descending below the fluid metal, and forming for the time the bed on which the metal rests. In some cases the shelves may be dispensed with, which will allow the metal quietly to slide over the highly heated surface of the interior of the furnace, the fuel floating on the surface of the metal. In either case it will be understood that the axes of the furnace will be made hollow, and of such a diameter as to admit the blast

pipe at one end, while the opposite one is made large enough to admit the fuel and metal, and at the same time serve as a means for the products of combustion to escape."

The manner in which I carry into practical operation this part of my said invention will be better understood by reference to sheet A of the drawings hereunto annexed, where figure 1 is a longitudinal section, and figure 2 a cross-section, of a cylindrical furnace, the axis of which is horizontal, and is supported at each end on hollow trunnions B and C, which rest in standards D. The outer shell of the furnace A, I prefer to form of stout plate iron, with one end made of cast iron, having the trunnion C formed upon it; around its outer edge, I form a row of cogs, by means of which rotatory motion is communicated to the furnace through the pinion E and shaft F, which may be actuated by any first mover. The outer shell of the furnace A is lined with firebricks A^1, some of which are made to project inwards beyond the rest, as shewn at A^2, and thus form shelves or buckets, for the purpose of lifting up the fluid metal and allowing it to fall again through the incandescent fuel. G is a pipe through which the blast is conducted into the furnace, a closely fitted joint being formed at G*, where the fixed end of the pipe G enters the revolving hollow trunnion C. At the opening B the fluid crude metal intended to be refined may be run into the furnace, and through this opening, also a supply of fuel may be thrown into the furnace from time to time, while it also serves as a means of escape for the products of combustion. In using this apparatus a fire is first to be lighted in the furnace, and a blast of air should be conveyed from a blowing fan into it by means of the pipe G; the furnace should then be put in motion, whereby the whole of its interior surface will become highly heated. When the fuel is in a state of vivid combustion, and the interior of the furnace is highly heated, a charge of fluid crude iron may be poured or run in at the opening B, when it will be found that the projecting parts A^2 will lift up the portions of metal, and pour it into and among the burning mass of fuel, and expose it to the action of the blast of air, whereby its refinement will be effected, and its temperature raised, and which will be further assisted by the highly heated interior surface of the furnace constantly descending below the surface of the fluid metal, and thus for the time forming the bed on which the metal rests. When the workman judges that the metal has been sufficiently decarbonized for his purpose, he will stop the rotation of the furnace, and proceed to discharge the fluid metal by opening the tap-hole H, which must be stopped with loam during the process, as commonly practised in cupola furnaces used for remelting iron. This apparatus may be modified so as to cause the fluid metal to slide quietly over the heated surface of the interior of the furnace, by omitting the projecting parts A^2, and thus forming a plain cylindrical furnace, as represented in cross-section at figure 3, sheet A, all the other arrangements of the apparatus being the same as shown at figures 1 and 2. Although the horizontal revolving furnace, herein lastly described, has the advantage of always presenting a newly heated

1341

surface for the metal to rest on, it nevertheless does not present so large a surface of fluid iron to the action of the fire and to the decarbonizing action of the blast, as may be obtained by causing the furnace to revolve on a vertical axis in the manner hereinafter described, and which modification of furnace I prefer for the purpose of refining iron, until so much of its carbon has been driven off as to give to the said crude iron the properties of, or to convert it into, steel, or pure or nearly pure refined iron. And here I would observe that for ordinary purposes coke may be used for fuel for carrying into effect my said invention, although I in all cases when the quality of the metal is of great importance prefer to use charcoal, wood, or prepared peat, as the effect of such last-named fuels are less injurious to the metal than coke made from mineral coal.

In constructing furnaces to revolve on a vertical axis, the cylindrical form is most suitable; the outside shell, being made of strong boiler plate soundly rivetted, is to be lined with firebrick, and coated with loam, the upper part being closed partly over, having a central hole at the top of about one-third the diameter of the furnace; the bottom of the furnace is formed of cast iron, strongly ribbed and keyed on to a spindle; the foot of this spindle rests in a footstep sunk several feet below the ground level, the upper part of the spindle working in a bearing formed in an iron frame secured to heavy masonry; this spindle has keyed upon it a wheel, by which a rapid rotary motion is given to it. A fire having been made in the furnace, and a powerful blast applied to it, either 1342 through the centre of the furnace at bottom, or by nozzles at the sides, which communicate with a hollow space around the axis; when the interior of the furnace is brought up to an intense heat the fluid iron may be run into it, and a rapid motion communicated to the furnace, whereby the fluid metal will rise up the sides of it as far as where the top closes over, and be there suspended by centrifugal force, the metal being distributed in a cylindrical layer of a few inches only in thickness; the fuel and heated vapours will by the same agency be pressed continually in contact with the fluid metal, and act powerfully thereon. By diminishing and increasing alternately the speed of the furnace, the metal will rise up or sink lower down in the furnace, and thus afford constantly fresh surfaces to the action of the fire and oxygen present in the furnace, which, by combining with the carbon contained in the iron, will refine and purify it to the required extent. In some cases, however, I find it preferable to introduce a fireclay pipe into the fluid metal in the bottom of the furnace, and by means of it force a current of hot air into and among the fluid metal; when the metal is somewhat cooled, the pipe may be withdrawn, and the motion of the furnace continued until it has been again heated up, when the process of blowing air or steam through the fluid metal may be repeated; and here I would remark that hot or cold air may be used, but I prefer hot blast, and that it should be heated to the highest practicable limit. As soon as the complete refinement of the metal is effected, the motion of the furnace may be discontinued, and the fluid steel or iron be tapped out of the side of the furnace, as usually

practised in cupola furnaces used for smelting iron; the metal so run out being received into suitable ingot moulds, whereby blocks of metal will be formed suitable for hammering or rolling into bars, plates, rails, or rods, and which may be either hard steel or soft steel, hard iron or soft iron, according to the extent of the refining process. And here I would observe, that when I desire to make steel of a superior quality, I carry out the refinement of crude iron as far as possible, and produce thereby soft iron, which I cast while in a fluid state into ingots, which I afterwards roll into bars or rods of the desired form and size; the iron bars thus formed I cement with charcoal, in the manner already practised in making blister steel; but the cemented bars made from cast ingots of iron will not form blisters, in consequence of their freedom from iron scales. When the process of cementation has been carried to the desired extent, the bars are removed from the cementing chest, and again rolled or tilted as already practised in the manufacture of steel."

In order that this part of my said invention may be fully understood, I have hereunto annexed a sheet of drawings, marked
1343 B, on which a centrifugal revolving furnace is shown; figure 1 being a vertical section thereof, and figure 2 a horizontal section of the same.

(Here follows diagram marked p. 1350.)

a is the outer casing of the furnace, which I prefer to make of rivetted iron plates; the bottom *b* of the casing is made of cast iron, and strengthened by ribs b^1, which extend from the central boss b^2, to the outer edge, and thus affords a strong support for the furnace; *c* is a shaft, the top part of which is keyed into the boss b^2, its lower end resting in a brass footstep or bearing *d*; the upper part of the shaft *c* works in brasses *e*, which are let into the foundation plate *f*; this plate is of sufficient size to cover the vacant space *g*, left in the foundation or masonry *h*; to this masonry it is securely fixed by bolts *i*. A bevilled wheel *j* is keyed on the shaft *c*, by means of which a rotary motion may be communicated from the bevilled wheel *k*, which is keyed on an axis *l*, and which receives motion from a steam-engine or other first mover, and thus, when required, the whole apparatus may be put in motion. The casing *a* is lined with firebrick coated with loam or other suitable refractory substance, the shape of which may be very accurately and easily formed by a moulding board or template, as practiced in making the moulds in loam that are used in iron-founding, the movement of the furnace on its axis *c* affording great facility for this operation. The furnace thus lined up with loam may be considered simply as a revolving cupola or blast furnace, and should be supplied with a powerful blast of air, which I prefer to be highly heated. In order to keep up the communication with the blast while the furnace is in motion, I form an annular chamber *f** around the part occupied by the brasses *e*; below the chamber *f**, I attach the blast pipe *m*; a similar annular chamber is formed at b^3 in the bottom plate *b* of the furnace casing, on the upper side of which there is also formed

a chamber b^5, having a central orifice, over which the tuyere pipe n is fixed, and thus a communication may be at all times kept up between the blast pipe m and the tuyere pipe n, the air from the blast pipe entering the lower part of the annular chamber f^*, and passing through two or more holes f^1 into the chamber b^3, and upwards through two or more holes b^4 into the space b^5, and from thence into the tuyere pipe n; to prevent the escape of air by the joint formed between the revolving plate b and the fixed plate f, a packing ring z is fitted to the plate b, and is allowed to rest on the plate f at a part where its surface is raised and is made smooth and even. The exterior of the pipe n is defended by a coating of loam, with which the lower cavity p of the furnace is also formed; above the mouth of the tuyere pipe is a dome-shaped fire-tile r, having several holes r^* passing through it in direction upwards, and at such an angle as to direct the blast which passes through them upon the surface of the fluid metal s, which is shown as oc-
1344 cupying a sunk channel, extending entirely around the inside of the furnace. The action of the apparatus is as follows:—Some lighted fuel is first put upon the tile r, and good hard coke or charcoal is put upon it; a moderate blast is then applied through the pipe m, so as to bring up the heat of the furnace gradually; more fuel is added, and the full power of the blast put on, so as to bring the interior surface of the furnace up to the highest degree of heat attainable; the shaft c is then put in motion, carrying with it the blast or cupola furnace. A spout u is then put into the open mouth of the furnace, its lower curved end being placed near the conical part of the lining v, as shown in figure 1; crude iron in a fluid state is then allowed to flow into the spout u, which will direct the stream of fluid iron against the conical part v, the metal will thereby be caused to rotate with the furnace, and will require so much centrifugal force as to keep it in close contact with its interior surface; in its tendency to fly further from the centre of motion, it will pass down the conical part v, and be collected in the cavity s, as shown in the drawings, where it is to be suspended during the decarbonizing process; the spout u is then to be removed, and a powerful blast is to be kept up; the air issuing from the orifices r^* will produce an intense ignition at a number of points near the surface of the metal. It will be understood that a slight alteration of the speed of rotation will cause a movement of the fluid particles, and thus constantly bring fresh portions of the fluid zone of metal to the inner surface, and expose all parts in turn to the decarbonizing action of the blast. The centrifugal force operating to keep the metal suspended will drive the fuel in close contact with it, and also carry the currents of heated vapour as far outward as possible, and thus cause them to impinge continually on the surface of the fluid metal. By this means the intense heat required to maintain steel or pure iron in a molten state will be obtained and applied to the large surface of metal exposed. Whenever the process has arrived at the desired point, the blast may be shut off, and the rotation of the furnace stopped; the metal will then rush downward and pass through the holes r^* into the chamber p, where

it will accumulate. On one side of the furnace there is a tapping hole, not shown in the drawings, but made precisely similar to the tapping holes of an ordinary cupola or blast furnace; this hole is to be quickly opened, and the fluid metal allowed to flow out into moulds, as required; the tap-hole may then be closed with loam and secured with an iron strap, the blast turned on, and the furnace recharged with metal, as before described, so as to produce a repetition of the process. The charging on of the fuel from time to time may take place while the furnace is in motion, for as the fuel becomes consumed, the centrifugal action of the furnace will cause fresh portions of it to leave the central part, so that a
1345 vacant space will be left for fresh fuel, which will fall into the centre, and thus the influx of cold fuel will not affect the high temperature required at those parts in close proximity to the fluid metal. In this particular form of apparatus the metal should not be let down into the lower part of the furnace until it is ready to be discharged, because the chamber *p* is too cold to allow it to remain in the fluid state. I therefore sometimes construct the centrifugal blast furnace as represented at figures 3 and 4, which show so much of the furnace as will enable this particular modification of it to be understood.

In the vertical section, figure 3, I have shown two passages A, A, formed on opposite sides of the bottom plate of the furnace; these passages continue upwards at A*, and terminate in tuyere pipes B, which enter the furnace on two opposite sides, as shown in the cross section at figure 4; on the passages A* there are small doors C, by means of which access may be had to the interior of the furnace, if necessary.

It will be observed that the tuyere pipes are surrounded by a mound of loam D, which serves to protect the pipes from the too violent action of the heat, and to prevent the metal from entering the tuyeres when the furnace is first set in motion; the metal in that case will rise upward at those parts furthest from the centre, passing up by the sides but not in front of the mounds D. When this modification of the apparatus is used, the furnace is to be heated as much as possible, the fluid iron is then run in among the fuel, and will thus rapidly find its way to the lower part E of the furnace, as shown in the drawings; the blast from the tuyeres being directed on to its surface, a partial refinement of the metal will soon take place, which, however, cannot be carried very far, or the metal would become solidified. While the partial decarbonization of the metal has been going on, the surface of the sunk channel G will have become intensely heated; the furnace is then to be put in motion in the manner hereinbefore described in reference to figure 1. The fluid metal in the lower part E of the furnace will thus be made to revolve, when the centrifugal force which its particles acquire by rotation will cause it to ascend the inclined sides of the furnace, and accumulate in the space G, where it will evenly distribute itself, and remain suspended so long as the proper speed of the apparatus is kept up. While occupying this position it will become intensely heated and still further decarbonized. Meanwhile

the hearth or sole of the furnace will have again been heated. The rotation of the furnace may then be stopped, when the metal will again sink down and occupy the lower part E of the furnace, the metal resting on the newly heated surface of the hearth, and will thus again be brought under the direct and powerful decarbonizing action of the blast. In this way the alternate rising up and
1346 lowering down of the charge of metal may take place until the desired amount of decarbonization or refinement has been effected. The state of the metal may be ascertained from time to time *to time* by letting out a small quantity of it by the tap hole, which is made in the side of the furnace, as before described in reference to figure 1. When the metal is required to form steel, I put into the furnace during the process of refining about one or two per cent. of oxide of manganese and one or two per cent. of common salt and of potashes, and one per cent. of lime when coke is used as fuel; but when charcoal is used, I omit the potashes, because the ashes or residuum of charcoal will form a sufficient flux without the use of potashes; and when the refinement of the iron is desired to be carried to the extent of depriving the metal of its carbon as far as practicable, and thus produce soft malleable iron, I entirely omit the use of manganese, using lime and salt only as a flux when charcoal is used as fuel, and lime and potashes when coke is used. When the crude iron to be refined contains sulphur, I pass jets of steam through the fluid metal. The steam is thus decomposed, producing both oxygen and hydrogen gas; the latter combines with the sulphur, and carries it off in the form of sulphuretted hydrogen, while the oxygen gas combines with the carbon of the crude iron, producing combustion accompanied by the disengagement of carbonic acid gas or carbonic oxide. When, however, the decarbonization of the metal is the chief object sought, atmospheric air may be used in lieu of steam, or the two may be used together. One of the modes by which this may be carried into effect in the centrifugal blast furnace is represented at figure 5, on the annexed sheet of drawings, which is a vertical section taken through the centre of the furnace, and figure 6 is a horizontal section of the same. The general arrangement of the furnace and the mode of driving it are the same as hereinbefore described in reference to figure 1. The steam or air intended to be forced into or through the fluid metal is conveyed from an air forcing pump or from a steam boiler up the central axis N, which is made tubular for that purpose, the lower end of it passing through a suitable stuffing box formed on the air or steam pipe. The bottom plate of the furnace casing has two passages P formed in it, which communicate with the hollow axis N in the centre, and with the elbow pipes Q. Around the exterior of the outer casing R of the furnace is a circular chamber S, to which the pipes Q, Q, are attached, so that a communication may at all times be kept up between the air pump or steam boiler and the space or chamber S. On the interior of the casing R there are small flange rings T, arranged in rows of three at several different parts of its circumference. Into these

angle rings are fitted small conical pieces of well-baked
1347 fire clay U, having a small opening through them. They are made secure by red lead or other cement, and kept in place by a screw plug V, which is secured into the chamber S. These plugs are hollow, and have cross passages formed in them so as to admit the air or steam freely to the hole in the small fire cones U, which can be removed at any time by unscrewing the plug V. It will be observed that the cones of fire clay do not extend quite through the lining of the furnace, which is made to enclose them so as to present only their smallest end to the action of the metal. When this modification of my invention is used, the fire is made in the interior, as before described in reference to figure 1, the blast being supplied by two tuyere pipes, which are arranged in a similar manner to that shewn in figure 3, but which are not seen in figure 5 in consequence of their being formed at right angles to the passages P, P; the orifice of one of them is, however, shewn at W, figure 5, and at W, W, figure 6. By means of the blast from the tuyeres W, the requisite amount of heat may be obtained to keep up the fluidity of the metal during the decarbonizing or refining process. It will be understood that the pressure of the steam or air forced through the holes in the cones U must always exceed the pressure exerted by the centrifugal force of the metal over a given area, in order to prevent any of the metal from entering the cones. It will be necessary that the air or steam should always be turned on previous to giving motion to the furnace. When air alone is used, it may be allowed constantly to blow through them, as these numerous small though powerful jets will cause an intense combustion at the exterior parts of the cylindrical mass of fuel, and thus heat the interior surface of the furnace to a very high temperature, in contact with which the metal will be forced whenever the furnace is put in motion at the required velocity.

Having thus described my invention, and the manner in which the same may be carried into effect, I desire it to be understood that I do not confine myself to the precise details herein specified, provided that the peculiar character of my invention be retained; but what I do claim, firstly, is the conversion of fluid crude iron into steel or into malleable iron by exposing the metal to the decarbonizing action of currents of air in furnaces, through which the metal is allowed to fall for that purpose. And also in the manufacture of iron and steel, the alternate rising and lowering of two furnaces, so as to allow the fluid metal to flow from one to the other in the manner and for the purposes before described.

Secondly, I claim, in manufacturing malleable iron and steel from crude iron while still in a fluid state, the use of revolving
1348 furnaces, having apparatus in the interior for the purpose of elevating portions of the metal, and allowing it again to fall in streams or showers when exposed to the action of currents of air passing through the furnace.

Thirdly, I claim, in the manufacture of iron and steel, the suspension of the fluid metal in a furnace by means of centrifugal force generated by the rotation of such furnace, and the forcing into,

through, or upon the fluid metal so suspended currents of air or steam.

Lastly, I claim the manufacture of bars, rods, or plates of steel by the cementation of bars or rods of malleable iron that have been obtained by the direct conversion of crude iron into malleable iron, and while still in a fluid state cast in suitable moulds.

In witness whereof, I, the said Henry Bessemer, have hereunto set my hand and seal, this fourth day of July, in the year of our Lord one thousand eight hundred and fifty-six.

HENRY BESSEMER. [L. S.]

Witness:

GEO. PITT,

4, *Old Square.*

London: Printed by George Edward Eyre and William Spottiswoode, printers to the Queen's most excellent majesty. 1856.

1351 [British coat of arms.]

A. D. 1856. No. 2061.

Smelting Ores.

Letters patent to John Loude Tabberner, of No. 4, Trafalgar square (office for patents), Charing Cross, in the county of Middlesex, for the invention of "certain improvements in smelting ores."

Sealed the 3rd March, 1857, and dated the 4th September, 1856.

Provisional specification left by the said John Loude Tabberner at the office of the commissioner of patents, with his petition, on the 4th September, 1856.

I, John Loude Tabberner, of No. 4, Trafalgar square (office for patents), Charing Cross, in the county of Middlesex, do hereby declare the nature of the said invention of "certain improvements in smelting ores," to be as follows:

This invention consists in a new and peculiar construction of furnace, having for its object, firstly, a more expeditious mode of smelting ores than those hitherto employed for such purpose; and, secondly, for improving the condition or character of the metal of the ores when reduced to a molten state, by the use and employment of such said furnace, and in conjunction therewith, the application of blast, either hot or cold.

The principal features in this invention consist in directing the blast to the body or belly of the furnace, as well as to the hearth thereof, for the purpose of fusing or smelting the entire mass of ore in the furnace simultaneously, or nearly so. This may be
1352 effected by constructing the boshes of the hearth of the furnace of a pyramidical or conical form, with innumerable holes through the same for preventing the furnace from choking, it being proposed by this invention to crush the ores into particles, to enable the metallic portion thereof to be more readily acted upon by the heat than when the furnace is charged with large lumps or cobs, as hitherto practised in smelting furnaces. Into the belly of the furnace tuyere pipes are built for the admission of the blast thereinto; said pipes being in connection with vertical and horizontal main pipes, fitted with slides or dampers for regulating the quantity of blast admitted to any particular part of the furnace. The lower part of the vertical blast pipes pass through small furnaces, in which fires (when hot blast is required) are kindled, the heat wherefrom passes up and along flues, in which the vertical and horizontal main pipes are placed for heating the air as it passes through and along the same. And it would be well here to remark, that the mode hitherto generally practised in smelting furnaces has

been to direct blast into the hearth only thereof, thereby requiring several hours to smelt or fuse the contents of a large furnace.

The object and intention of this invention is, therefore, to dispense with the necessity for employing one or more large furnaces, and to use in lieu thereof several small furnaces, the combined capacities whereof are equal to that of one or more large furnaces, and to cause these small furnaces to discharge their contents at short intervals of time into one large reservoir, from which the molten metal may be drawn for casting from. And it is this mode of constructing and arranging furnaces and the directing of blast to any particular part thereof at discretion, which constitutes this invention.

Specification in pursuance of the conditions of the letters patent, filed by the said John Loude Tabberner in the Great Seal patent office on the 4th March, 1857.

To all to whom these presents shall come, I, John Loude Tabberner, of No. 8 Lorn road, North Brixton, in the county of Surrey, send greeting:

Whereas her most excellent majesty Queen Victoria, by her letters patent, bearing date the fourth day of September, in the year of our Lord one thousand eight hundred and fifty-six, in the twentieth year of her reign, did, for herself, her heirs and successors, give and grant unto me, the said John Loude Tabberner, her special license that I, the said John Loude Tabberner, my executors, administrators, and assigns, or such others as I, the said
1353 John Loude Tabberner, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel islands, and isle of Man, an invention for "certain improvements in smelting ores," upon the condition (amongst others) that I, the said John Loude Tabberner, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal patent office within six calendar months next and immediately after the date of the said letters patent.

Now know ye, that I, the said John Loude Tabberner, do hereby declare the nature of the said invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement thereof, that is to say:—

This invention consists in a new and peculiar construction of furnace, having for its object, firstly, a more expeditious mode of smelting ores than those hitherto employed for such purpose; and, secondly, for improving the condition or character of the metal of the ores when reduced to a molten state, by the use and employment

of such said furnace, in conjunction therewith, the application of blast either hot or cold.

The principal features in this invention consist in directing the blast to the body or belly of the furnace, as well as to the hearth thereof, for the purpose of fusing or smelting the entire mass of ore in the furnace simultaneously, or nearly so. This may be effected by constructing the boshes of the hearth of the furnace of a pyramidical or conical form, with innumerable holes through the same for preventing the furnace from choking, it being proposed by this invention to crush the ores into particles to enable the metallic portion thereof to be more readily acted upon by the heat than when the furnace is charged with large lumps or cobs, as hitherto practised in smelting furnaces. Into the belly of the furnace tuyère pipes are built, for the admission of the blast thereinto; said pipes being in connection with vertical and horizontal main pipes, fitted with slides or dampers for regulating the quantity of blast admitted to any particular part of the furnace. The lower part of the vertical blast pipes pass through small furnaces, in which fires are kindled when hot blast is required, the heat wherefrom passes up and along flues, in which the vertical and horizontal main pipes are placed for heating the air as it passes through and along the same.

1354 And it would be well here to remark, that the mode hitherto generally practised in smelting furnaces has been to direct blast into the hearth only thereof, thereby requiring several hours to smelt or fuse the contents of a large furnace.

The object and intention of this invention is, therefore, to dispense with the necessity for employing one or more large furnaces, and to use in lieu thereof several small furnaces, the combined capacities whereof are equal to that of one or more large furnaces, and to cause these small furnaces to discharge their contents at short intervals of time into one large reservoir, from which the molten metal may be drawn for casting from. And it is the above principle of constructing and arranging furnaces, and the directing of blast to any particular part thereof at discretion, which I claim as constituting my invention of improvements in smelting ores.

In witness whereof, I, the said John Loude Tabberner, have hereunto set my hand and seal, this fourth day of March, in the year of our Lord one thousand eight hundred and fifty-seven.

JOHN LOUDE TABBERNER. [L. S.]

Witness:

ALEX'R PRINCE,

Agent for Patents, 4 *Trafalgar Square, Charing Cross.*

London: Printed by George Edward Eyre and William Spottiswoode, printers to the Queen's most excellent majesty. 1857.

1355 [British coat of arms.]

A. D. 1869, 23rd February. No. 566.

Manufacture of Steel and Iron.

Letters patent to Henry Bessemer, of Queen Street place, Cannon street, in the city of London, for the invention of "improvements in the construction and arrangement of machinery, *apparatus*, and buildings employed in or for the manufacture or production of cast steel and malleable iron from pig or other carburet of iron."

Sealed the 13th July, 1869, and dated the 23rd February, 1869.

Provisional specification left by the said Henry Bessemer at the office of the commissioners of patents, with his petition, on the 23rd February, 1869.

I, Henry Bessemer, of Queen Street place, Cannon street, in the city of London, do hereby declare the nature of the said invention for "improvements in the construction and arrangement of machinery, apparatus, and buildings employed in or for the manufacture or production of cast steel and malleable iron from pig or other carburet of iron," to be as follows:

The production of ingots or other masses of cast steel or malleable iron from pig or other carburet of iron by the forcing of atmospheric air upward through the molten metal, and now generally known as the Bessemer process, consists of several distinct
1356 operations carried on in succession. The most important of these operations consist in melting the pig metal, transferring it in the molten state to the converting vessel, blowing air through it, and converting it into a malleable metal, mixing the metal so converted with a certain quantity of fluid manganesian pig iron, pouring the mixed metals into a casting ladle, and running it from thence through a suitable valve into ingot or other moulds, and the removal therefrom of the ingots or other cast masses when solidified.

Now it is essential to the economic performance of these successive operations that the several kinds of apparatus employed should occupy such positions in reference to each other that no unnecessary time should be employed in passing the metal from one to the other, that the metal in its fluid state should not be unnecessarily cooled by exposing it to radiation in open gutters of great length, and that the motion of the several parts of the apparatus should be capable of being effected with ease and certainty, with a view to economize time, save labor, retain heat, and conduct the process with safety. These objects are sought to be accomplished by the several arrangements or combinations of apparatus hereinafter described, and at the same time the first cost of the combined apparatus will be much

reduced as compared with the cost of the apparatus now generally employed in the manufacture of Bessemer steel and iron, while the size and cost of the necessary building will also be much reduced.

In carrying into practical operation the objects set forth I prefer to place two or more converting vessels in such a position with reference to each other that their respective axes are in a straight line, the axes being at a distance of three or four feet above the general floor level. Beneath each vessel a small pit is formed, and an arched passage passes from one pit to the other in the line of the vessel's axes and terminating beyond the building, so that by means of a line of rails laid in this passage the ashes or other debris of the operation may be readily removed on trucks moving on these rails. An incline or a lift may be employed to raise the trucks up to the general ground level. In front of each vessel I mount a casting ladle on the top of a vertical slide or ram, the upper part of the slide or ram having a table for the ladle to stand upon, or having two supports for the axes of the ladle. Should it be desired to make the ladle moveable so as to discharge the slag by turning it over without removing it from the table the ram or slide has a vertical movement given it by means of hydro-
1357 static pressure acting in the cylinder in which the ram works, or it may be moved up and down by a screw and worm wheel similar to Healey's patent screw jack, or it may be moved by forming a rack upon the ram or slide actuated by a pinion on a revolving shaft. The casting ladle so mounted will be lowered as the metal from the converter is poured into it, after which it will be raised again so high that its under side will rise above the top of the moulds, which are to be brought successively under it, and be filled by means of the valve arrangement now generally employed in casting Bessemer steel. In front of the casting ladle I mount a circular bed or table on a vertical spindle, the upper surface of which I protect with brick, fire-tiles, or sand; on this table the moulds are placed in a concentric circle; a hollow or indented part is formed or cut out on one side of the table to allow the casting ladle to rise up past it; the table may be rotated by gearing, or simply by a hand spike or lever, and thus each mould will be quickly and with little force brought under the ladle to be filled. Against or near to the side walls I fix small cranes to lift off the ingot moulds and ingots from the revolving tables, and transfer them to trucks moving on rails laid in a line parallel to the line of converting vessels.

By another arrangement the turntables may be replaced by a line of rails on which a series of low trucks are moved and on which the moulds are placed, so that the trucks and moulds may be moved beneath the casting ladle in a line parallel to the axes of the converting vessels, and be filled in succession; or in lieu of using trucks wheels may be fitted to axes attached to the bed of the moulds, and capable of easy adjustment to new beds as the beds become worn out. The trucks or moulds on wheels may be moved by hand, but I prefer to employ an endless wire rope or chain passing beneath them and over suitable pulleys, so that by taking a

grip on the rope with a suitable lever attached to the trucks or moulds they may be moved or allowed to remain at rest as desired; by mounting each mould bed on three or four wheels great facility is afforded for their general movement from place to place. Both when using the line of rails or the circular table to move the moulds I prefer to place the cupola melting furnaces before the converting vessels or nearly so, so that when the vessels are turned down to receive a charge of molten iron the mouth of the vessels shall approach nearer to the cupola. When two converting vessels are used I prefer to employ two large cupolas, but when a greater number than two converting vessels are used in a line the
1358 arrangement and number of cupola furnaces may be varied to suit the requirements of the manufacturer and the hours of working; but in all cases I prefer to have one casting ladle and one turntable for each converter, if turntable be employed. The cupola furnace may be of the ordinary kind used by founders, but I prefer to employ the description of cupola known as "Ireland's upper tuyere furnace" or "Woodward's steam jet cupola." In either case in a line between the cupolas, but preferably nearer to the converting vessels, I mount a ladle or receiver on a weighing machine with a short spout from each cupola leading into it, so that the charge of iron to be converted is first run into this receiver and weighed. Beneath the tap hole of receiver is placed the enlarged end of a swinging gutter by which the iron may be run (above the level of the turntable or line of moulds and trucks) into the mouth of the converter. The turning of the vessels on their axes may be effected by a small steam or air engine having reversing gear similar to that generally employed in steam cranes or winding engines used in mines. A large spur wheel or wheels may be employed in connection with the axes of the vessels, and a reversing clutch so arranged that either vessel may be moved separately; a large worm wheel, however, is to be preferred to spur gearing either as a first or second motion as it has no tendency to run back or reverse the engine; or in lieu of this a separate engine may be employed to each axis of the converters at their outside ends, in which case the air will be admitted at the axes that come near each other between the vessels. The winding engines and the cranes employed to move the ingots may be actuated by steam, or the compressed air or blast may be used in lieu thereof if desired. The winding engine instead of being placed between or at the outer ends of a pair of converting vessels may be placed at any convenient part of the converting house and transmit its power to the vessels by means of shafting, and may in such case by similar means be employed to work the cranes for removing the ingots and moulds and for actuating the lifts for raising the pig metal to the upper floor and raising the debris from the casting pits. When the winding engine is used between the vessels I prefer to build a wall on each side thereof, and to spring a brick arch over it, and in like manner I carry an arch above the mouth of the converters so that the flame and heated gases may not rise to the roof of the building but escape through suitable openings made in the

brick wall for that purpose. When two converting vessels are grouped as described I also employ two small cupola furnaces for melting the manganesian carburet of iron or spiegel
1359 eisen; these may be placed near the weighing ladle and the iron from them be run into the vessel or casting ladle along the gutters before-named, but I prefer to tap these small furnaces into a swing or travelling ladle, where the iron may be weighed, and be thus transferred to the converter or casting ladle without being cooled or wasted by passing along a gutter. I prefer to form an upper floor on girders and arches at that part of the converting house where the cupola furnaces are situated, on to which floor the metal and fuel may be hoisted by a suitable lift. The cupola furnaces may form a support for the iron floor beams at the central part, the outer walls of building supporting the other ends of them. The trunnion bands generally employed in converting vessels are of forged iron, and from the difficulty of making them are very expensive; I therefore replace them in some cases by employing a hoop of cast iron with the trunnions and air passages formed therein. In this case I use rolled angle irons to embrace the cast-iron hoop, and by passing bolts entirely through the cast iron and rolled angles the several parts of the cast-iron hoop would be supported in case of accidental fracture; or in lieu of this mode I make the central band of plate iron or steel which forms part of the vessel thicker than the other parts of it, and secure to it the trunnions by a flange, using by preference for the trunnion steel castings, or iron or steel forgings; the central part of the vessel may be further stiffened by angle rings rivetted around it above and below the trunnion flanges.

Specification in pursuance of the conditions of the letters patent, filed by the said Henry Bessemer in the Great Seal patent office on the 23rd August, 1869.

To all to whom these presents shall come, I, Henry Bessemer, of Queen Street place, Cannon street, in the city of London, send greeting:

Whereas her most excellent majesty Queen Victoria, by her letters patent, bearing date the twenty-third day of February, in the year of our Lord one thousand eight hundred and sixty-nine, in the thirty-second year of her reign, did, for herself, her heirs and successors, give and grant unto me, the said Henry Bessemer, her special licence that I, the said Henry Bessemer, my executors,
1360 administrators, and assigns, or such others as I, the said Henry Bessemer, my executors, administrators and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel islands, and isle of Man, an invention for "improvements in the construction and arrangement of machinery, apparatus, and buildings employed in or for the manufacture or production of cast steel and malleable

iron from pig or other carburet of iron," upon the condition (amongst others) that I, the said Henry Bessemer, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal patent office within six calendar months next and immediately after the date of the said letters patent.

Now know ye, that I, the said Henry Bessemer, do hereby declare the nature of the said invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement thereof, that is to say:

The production of ingots or other masses of cast steel or malleable iron from pig or other carburet of iron by the forcing of atmospheric air upward through the molten metal, and now generally known as the Bessemer process, consists of several distinct operations carried on in succession. The most important of these operations consist- in melting the pig metal, transferring it in the molten state to the converting vessel, blowing air through it, and converting it into a malleable metal, mixing the metal so converted with a certain quantity of fluid manganesian pig iron, pouring the mixed metals into a casting ladle, and running it from thence through a suitable valve into ingot or other moulds, and the removal therefrom of the ingots or other cast masses when solidified.

Now it is essential to the economic performance of these successive operations that the several kinds of apparatus employed should occupy such positions in reference to each other that no unnecessary time should be employed in passing the metal from one to the other, that the metal in its fluid state should not be unnecessarily cooled by exposing it to radiation in open gutters of great length,

1361 and that the motion of the several parts of the apparatus should be capable of being effected with ease and certainty, with a view to economize time, save labour, retain heat, and conduct the process with safety. These objects are sought to be accomplished by the several arrangements or combinations of apparatus hereinafter described, and at the same time the first cost of the combined apparatus will be much reduced as compared with the cost of the apparatus now generally employed in the manufacture of Bessemer steel and iron, while the size and cost of the necessary building will also be much reduced.

In carrying into practical operation the objects set forth I prefer to place two or more converting vessels in such a position with reference to each other that their respective axes are in a straight line, the axes being at a distance of three to four feet above the general floor level; beneath each vessel a small pit is formed, and an arched passage passes from one pit to the other in the line of the vessel's axes, and terminating beyond the building, so that by means of a line of rails laid in this passage the ashes or other debris of the operation may be readily removed on trucks moving on these rails. An incline or lift may be employed to raise the trucks up to the general ground level.

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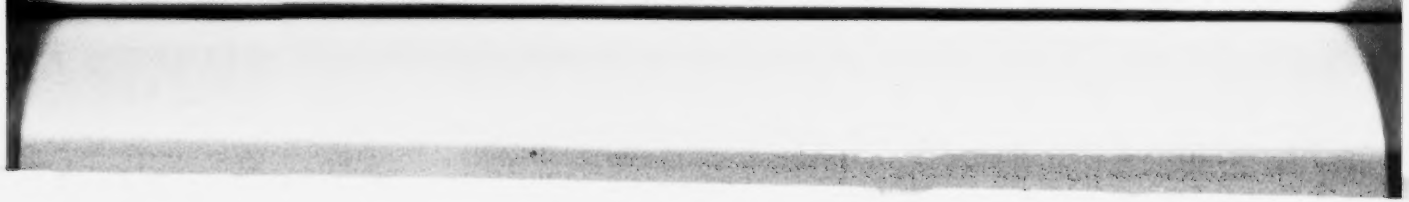


And in order that the arrangement and construction of the converting apparatus may be more fully understood, I have hereunto annexed a sheet of drawings on which the same is represented in plan at figure 1, and in vertical section at figure 2; a side elevation of the converting vessel showing the gearing for giving it rotation is shown at figure 3. The same letters of reference in these figures indicate a repetition of the parts so marked.

(Here follows diagram marked p. 1367.)

a, *a*, represent two converting vessels so placed that their respective axes are in a straight line, in which position any required number may be placed along one side of the "converting house;" the axes of the vessels are supported on massive castings *b*, the upper parts of which are formed into plummer blocks *b** for the axes to turn in; each of the converters *a* stands over a separate pit *u* through which an arched passage *c* leads to the outer sides of the building; in this passage are fixed the rails *d*, on which an iron truck *e* may be moved beneath any number of vessels placed in a line and receive from them the slags, cinders, or other debris, and convey it out of the converting house. The pipe and usual valve arrangement for the supply of air to the converter is shown at *f**. In front of each vessel I mount a casting ladle *g* on the top of a vertical
1362 slide or ram *h*, the upper part of the slide or ram having a table *i* for the ladle to stand upon, as shown, or having two supports for the axes of the ladle should it be desired to make the ladle moveable so as to discharge the slag by turning it over without removing it from the table; the ram or slide *h* has a vertical movement given it by means of hydrostatic pressure acting in the cylinder *k* in which the ram works, or it may be moved up and down by a screw and worm wheel similar to Haley's patent screw jack, or it may be moved by forming a rack upon the ram or slide actuated by a pinion on a revolving shaft. The casting ladle so mounted will be lowered as the metal from the converter is poured into it, after which it will be raised again so high that its under side will rise above the top of the moulds, as shown by dots at *g**; the moulds are to be brought successively under it by turning the table *m*, and be filled by means of the valve arrangement *f* now generally employed in casting Bessemer steel. In front of the casting ladle I mount a circular bed or table *m* on a vertical spindle *n* moving in a bearing *o* and foot step *o**; the upper surface of the table I protect with brick, fire-tiles, or sand *m**; on this table the moulds *p* are placed in a concentric circle; a hollow or indented part *q* is formed or cut out on one side of the table to allow the casting ladle *g* to rise up past it; the table may be rotated by gearing or simply by a hand spike or lever, and thus each mould will be quickly and with little force brought under the ladle to be filled. Against or near to the side walls I fix small cranes to lift off the ingot moulds and ingots from the revolving tables and transfer them to trucks moving on the rails *r* laid in a line parallel to the line of converting vessels; or in lieu of the wall cranes I use an hydraulic crane

such as is generally known as an ingot crane, and represented at *s*, figures 1 and 2, and placed between each pair of converting vessels, the range of the gib shown by dots *t* being such that the top of the converter or the tuyere box may be removed by it on to a truck moving on the rails *r*, and be carried out of the converting-house.

By another arrangement the turntables may be replaced by a line of rails on which a series of low trucks are moved, and on which the moulds are placed, so that the trucks and molds may be moved beneath the casting ladle in a line parallel to the axes of the converting vessels and be filled in succession; or in lieu of using trucks wheels may be fitted to and axes attached to the bed of the moulds, and capable of easy adjustment to new beds as the beds be-
1363 come worn out. The trucks or moulds on wheels may be moved by hand, but I prefer to employ an endless wire rope or chain passing beneath them and over suitable pulleys; so that by taking a grip on the rope with a suitable lever attached to the trucks or moulds they may be moved or allowed to remain at rest as desired; by mounting each mould bed on three or four wheels great facility is afforded for their general movement from place to place. Both when using the line of rails or the circular table to move the moulds I prefer to place the cupola melting furnaces A, A, before the converting vessels, or nearly so, as shown in the annexed drawings, so that when the vessels are turned down, as shown by dots at a^*, figure 2, to receive a charge of molten iron the mouth of the vessel shall approach nearer to the cupola A. When two converting vessels are used I prefer to employ two large cupolas, as shown at A, A, in the annexed drawings, but when a greater number than two converting vessels are used in a line the arrangement and number of cupola furnaces may be varied to suit the requirements of the manufacturer and the hours of working; but in all cases I prefer to have one casting ladle and one turntable for each converter, if turntables be employed. The cupola furnaces may be of the ordinary kind used by founders, but I prefer to employ the description of cupola known as "Ireland's upper tuyere furnace" or "Woodward's steam jet cupola." In either case in a line between the cupolas, but preferably nearer to the converting vessels, I mount a ladle or receiver B on a weighing machine C with a short spout D from each cupola leading into it, so that the charge of iron to be converted is first run into the receiver B and weighed. Beneath the tap hole of the receiver is placed the enlarged end E^* of a swinging gutter E by which the iron may be run (above the level of the turntable or line of moulds and trucks) into the mouth of the convertor. The moveable gutter or spout D is supported in a vertical spindle F, which is retained in position by a pedestal G bolted to the foundation; the spout E is capable of supplying both converting vessels, and when not in use may be moved out of the way by turning it in a direction parallel to the rails *r*. By this arrangement each of the cupolas may be employed to supply either of the convertors, the exact quantity of metal employed being ascertained by weighing it in the receiver B before running it into the converter.

The turning of the vessels on their axes may be effected by a

small steam or air engine having reversing gear similar to that generally employed in steam cranes or winding engines used
1364 in mines. A large spur wheel or wheels may be employed in connection with the axes of the vessels and a reversing clutch so arranged that either vessel may be moved separately; a large worm wheel however is to be preferred to spur gearing, either as a first or second motion, as it has no tendency to run back or reverse the engine.

In the accompanying drawing at figure 3 a large worm wheel H is shown on the axes of the converting vessel; a worm I on the vertical shaft J gears into the worm wheel, and is supported by the frame K bolted to the foundation. A bevilled wheel L is keyed on to the lower end of the shaft J, and is geared into another bevilled wheel M on the horizontal shaft N; this shaft extends entirely across the building, and is provided with any of the usual means of connection with a steam or air engine having a reversing valve gear, so that the shaft N may be put in motion, reversed, or stopped when required by a workman so placed that he can see the pouring out of the molten metal into the ladle, and be enabled to regulate the motion of the converter as found desirable; a clutch is also provided for the purpose of disengaging the bevilled wheel M, when the vessel to which it gives motion is required to be at rest; or in lieu of this arrangement a separate engine may be employed to each axis of the converters at their outside end, in which case the air will be admitted at the axes that come near each other between the vessels. The winding engines and the cranes employed to move the ingots may be actuated by steam, or the compressed air or blast may be used in lieu thereof if desired. The winding engine instead of being placed between or at the outer ends of a pair of converting vessels may be placed at any convenient part of the converting house, and transmit its power to the vessels by means of shafting, and may in such case by similar means be employed to work the cranes for removing the ingots and moulds, and for actuating the lifts for raising the pig metal to the upper floor and raising the debris from the casting pits. When the winding engine is used between the vessels I prefer to build a wall on each side thereof, and to spring a brick arch over it, and in like manner I carry an arch above the mouth of the converters, so that the flame and heated gases may not rise to the roof of the building, but escape through suitable openings made in the brick wall for this purpose. When two converting vessels are grouped as described I also employ two small cupola furnaces Q, Q, for melting the magnesian carburet of iron or spiegel eisen; these may be placed near the weighing ladle, as shown,
1365 and the iron from them be run into the vessel or casting ladle along the gutters before-named, but I prefer to tap these small furnaces into a swing or travelling ladle, where the iron may be weighed, and be thus transferred to the converter or casting ladle without being cooled or wasted by passing along a gutter. I prefer to form an upper floor on girders, as shown at R, figure 2, or on arches at that part of the converting-house where the cupola fur-

naces are situated, on to which floor the metal and fuel may be hoisted by a suitable lift; the cupola furnaces may form a support for the iron floor beams at the central part, the outer walls of building supporting the other ends of them. The cupola furnaces A and Q are erected on a raised bed of masonry S in order that the workman may have a platform or floor to stand on when tapping the furnaces; the steps T give access to this raised platform. The trunnion bands generally employed in converting vessels are of forged iron, and from the difficulty of making them are very expensive; I therefore replace them in some cases by employing a hoop of cast iron with the trunnions and air passages formed therein. In this case I use rolled angle irons to embrace the cast-iron hoop, and by passing bolts entirely through the cast iron and rolled angles the several parts of the cast-iron hoop would be supported in case of accidental fracture; or in lieu of this mode, I make the central band of plate iron or steel which forms part of the vessel thicker than the other parts of it, and secure to it the trunnions by a flange, using by preference for the trunnion steel castings, or iron or steel forgings; the central part of the vessel may be further stiffened by angle rings rivetted around it above and below the trunnion flanges.

Having described my invention, and the manner in which the same is to be carried into practical operation, I desire it to be understood that I do not confine myself to the precise details herein specified so long as the peculiar character of my invention is retained; but what I do claim is,—

Firstly. Placing two or more converting vessels with their respective axes in a line when used in combination with melting furnaces to which the mouths of the converters approach when turned down to receive the molten iron.

Secondly. I claim raising and lowering the casting ladle
1366 vertically in front of the converting vessel by the direct action of a hydraulic plunger or by a screw or rack, as described.

Thirdly. I claim employing in combination with such raising and lowering apparatus a turntable mounted on a vertical axis for bringing the moulds in succession under the casting ladle, as herein described.

Fourthly. I claim the movement of converting vessels on their axes by means of a worm and worm wheel and bevilled gearing, as herein described.

Fifthly. I claim the employment of a ladle or receiver for weighing molten cast iron so placed as to receive a charge of metal from two or more melting furnaces, and provided with a moveable gutter for the conveyance of the metal therefrom into two or more converting vessels.

Sixthly. I claim the mode herein described of receiving in a

truck on rails and conveying away the waste fuel and slags or other matters from the converting vessels.

Lastly. I claim the general arrangement and grouping together of the several implements or apparatus employed in the manufacture of Bessemer steel, as shown in the drawings hereunto annexed.

In witness whereof, I, the said Henry Bessemer, have hereunto set my hand and seal, this twenty-third day of August, in the year of our Lord one thousand eight hundred and sixty-nine.

HENRY BESSEMER. [L. S.]

London: Printed by George Edward Eyre and William Spottiswoode, printers to the Queen's most excellent majesty. 1869.

1368 [British coat of arms.]

A. D. 1872, 6th March. No. 685.

Manufacture of Bessemer Steel and Iron, &c.

Letters patent to Charles Denton Abel, of No. 20 Southampton buildings, Chancery lane, in the county of Middlesex, patent agent, for the invention of "improvements in the manufacture of Bessemer steel and iron, and in the production of iron castings and in apparatus therefor." A communication from abroad by Zoheth Sherman Durfee, of the city of New York, in the United States of America.

Sealed the 23rd August, 1872, and dated the 6th March, 1872.

Provisional specification left by the said Charles Denton Abel at the office of the commissioners of patents, with his petition, on the 6th March, 1872.

I, Charles Denton Abel, of No. 20, Southampton buildings, Chancery lane, in the county of Middlesex, patent agent, do hereby declare the nature of the said invention for "improvements in the manufacture of Bessemer steel and iron, and in the production of iron castings, and in apparatus therefor," to be as follows:—

1369 In the conversion of iron by the Bessemer process considerable economy would be effected by converting the crude iron immediately after it is tapped from the smelting furnace before it has lost its heat and fluidity. The difficulty in adopting this mode of operating arises from the variable character of the metal, which as it runs from the smelting furnace is sometimes of a quality unfit for conversion. One part of the present invention relates to a process and apparatus whereby this difficulty may be overcome. Between the smelting furnace (whether a blast furnace or a cupola furnace) and the converting vessel is introduced a reverberatory mixing furnace, by preference a gas furnace, of any suitable known construction into which the crude metal from the smelting furnace is run, and wherein it is mixed with pig iron of suitable qualities, or with iron or steel or metalloids, such as it may be desirable to alloy with the crude metal, fluxes being also supplied for giving the required fluidity and purity, and the usual tests as to quality being applied to the mixed metal. The metal thus treated is then run into the converting vessels of known construction, wherein it is subjected to the Bessemer process. By properly arranging the levels of the smelting furnace, the mixing furnace, and the converting vessels, the metal may be run direct from the one into the other without the necessity for hoisting ladles. Also the metal supplied for alloy in the mixing furnace may be poured or run into it in a liquid state from melting furnaces or cupolas situated near it. The metal may also be poured back from

the converting vessels into the mixing furnace in case of accidents occurring to the converting vessels, or when further admixture or refinement may be necessary.

The method herein described of producing uniformity of quality in iron for conversion by the Bessemer process may also be used for giving the desired quality and character to iron to be used in *making* castings of any kind. For this purpose a mixing furnace such as has been described above is employed in conjunction with the smelting furnace, and with the other furnaces or cupolas in which the selected metal is heated and melted. The crude metal from the smelting furnace being run into the mixing furnace, is there alloyed, or refined and tested, and the mixed metal is run thence into moulds so as to produce the required castings.

1370 Specification in pursuance of the conditions of the letters patent filed by the said Charles Denton Abel in the Great Seal patent office on the 4th September, 1872.

To all to whom these presents shall come, I, Charles Denton Abel, of No. 20 Southampton buildings, Chancery lane, in the county of Middlesex, patent agent, send greeting:

Whereas Her Most Excellent Majesty Queen Victoria, by her letters patent, bearing date the sixth day of March, in the year of our Lord one thousand eight hundred and seventy-two, in the thirty-fifth year of her reign, did, for herself, her heirs and successors, give and grant unto me, the said Charles Denton Abel, her special licence that I, the said Charles Denton Abel, my executors, administrators, and assigns, or such others as I, the said Charles Denton Abel, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel islands, and isle of Man, an invention for "improvements in the manufacture of Bessemer steel and iron, and in the production of iron castings, and in apparatus therefor," a communication to me from abroad by Zoheth Sherman Durfee, of the city of New York, in the United States of America, upon the condition (amongst others) that I, the said Charles Denton Abel, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal patent office within six calendar months next and immediately after the date of the said letters patent.

Now know ye, that I, the said Charles Denton Abel, do hereby declare the nature of the said invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement thereof, that is to say:—

In the conversion of iron by the pneumatic or Bessemer process,

a great saving of fuel and iron, of wear and tear of furnaces,
1371 and of labor, would be effected were it possible to make uniformly good products of the desired temper by converting the crude iron immediately it is tapped from the blast furnace in which it is made. This plan has been and may still be practiced to a considerable extent, but it has been found that by reason of the irregular working of blast furnaces, and the consequent varying character and quality of the crude iron produced, it was always very difficult and in most cases impossible to secure such uniformity in the converted metal as was essential to success in the business. Hence, at several establishments where the plan of taking the fluid iron as it was tapped from the blast furnace and pouring it at once into the converter has been practiced, it has been abandoned, the proprietors preferring to incur the expense of handling and remelting the crude iron after it had been cast into pigs, in order thus to secure the advantage of carefully selecting and mixing the materials for each charge to be converted.

Now in order to secure the greater portion of the saving due to taking the iron from the blast furnace to the converter without its being allowed to cool and solidify, and at the same time to obviate the disadvantages resulting from the variations in the character and quality of the blast-furnace product, and in order also to be able to mix irons to any desired extent, I propose to place at any suitable points near the converting vessels, and by preference at such height as will permit the metal to be run into the converters from them without previously hoisting the ladles into which the metal may first be tapped, reverberatory furnaces, by preference gas furnaces, into which furnaces the crude iron as it is brought from the blast furnaces may be poured, and wherein it may be mixed with other irons, and be so treated as to insure the metal from time to time tapped out for conversion being as nearly as practicable of a uniform character. So many and so large furnaces may be used as the work in progress may demand; but in many cases one furnace of about double the capacity of the converter in use will be sufficient, as the necessary correction of the character of the crude iron can be very quickly made. Gas furnaces offer especial advantages for this purpose, as they use much less fuel in maintaining a given temperature than do the ordinary reverberatory furnaces, and can readily produce the highest heat required.

After the iron from the blast furnace has been poured into the
reverberatory furnace, pig iron of different qualities, or any
1372 metals or metalloids which may be desired to mix therewith, may be introduced, and so also may any fluxes which may be useful.

Some qualities or grades of crude iron cannot advantageously be used in the Bessemer process, because they do not contain sufficient quantities of heat-giving elements, such as carbon and silicum, and consequently work cold, and the steel produced from them chills so quickly that it cannot be tapped from the ladles. Now with the use of gas furnaces as herein proposed, such metals can be so highly heated before they shall be poured into the converter that the lack

of heat-giving elements will be compensated, and as iron lacking such elements, chiefly the higher numbers of pig iron, is sold at lower prices than those irons which contain them, reverberatory furnaces may also in many cases be advantageously used when iron is to be remelted for conversion; and when in such cases it may be cheapest to use cupola furnaces for melting the pigs, I would place a reverberatory furnace at some convenient point between the cupola furnaces and the converters, and tap the iron from the cupolas into the reverberatory furnaces, and from thence, after first giving it the desired character and temperature, into the converter. It will be understood that these reverberatory furnaces will give all needed opportunity for testing the irons under treatment, and also superior facilities for remelting any ingots and scraps which require to be reconverted; and when reverberatory furnaces are used alone or in combination with cupola furnaces, arrangements may be made for hoisting any metal, which in consequence of derangements of the converters or any of the connected apparatus may require to be poured from the converters before it is completely converted, and pouring it into the reverberatory furnaces so that it may be prepared for being returned to the same converter from whence it was taken, if it shall have been repaired, or to some other which may be in order. In case gas furnaces are thus used in connection with cupola furnaces, the latter may be so constructed as that the waste gases therefrom may be taken off for working the reverberatory gas furnaces.

The before described method of producing uniformity of quality in iron for conversion by the Bessemer process may also be used for giving the desired quality and character to iron to be used in making castings of any kind.

Various attempts have been made from time to time to make castings from iron taken directly from smelting or blast furnaces, but nearly or quite all such operations have been abandoned, because the crude iron run directly from the smelting furnace or from ladles into which it had just been tapped into moulds was found to be too impure and too irregular in character to be relied upon for many of the castings desired.

1373

Now in order to obviate these disadvantages and to be enabled to suitably refine the iron tapped out of the smelting furnace, and then cast it into any desired form without suffering it to cool, and then remelting it, and also to be able to make conveniently mixtures of other irons with such iron as may be tapped from any smelting furnace whose product it may be desired to cast without allowing it to cool and then remelting it, I proceed as follows:—I place at any convenient point near the blast furnace, or within such distance that the crude metal tapped out from the blast furnace can be carried thereto without losing its fluidity, a reverberatory or other suitable furnace, preferably a gas furnace, such as the Siemens' regenerative gas furnace, or any similar furnace in which a high heat may be maintained at small cost of fuel, and in which the waste gases of the blast furnace can be used as fuel in whole or

in part, and I pour or run the metal tapped out from the blast furnace therein.

When the metal has been poured into the gas furnace it can be treated in any desired way to refine it, and any metals or alloys of metal can be added at will. The iron in the gas furnace can thus be kept at any given standard, and part of it tapped out from time to time as may be required for making casting of any desired quality, and it will be seen that this plan offers great advantages for the manufacture of high grades of castings, such as car wheels, malleable castings, &c., as the heat of the gas furnace can be so far raised as to melt or keep melted the most decarbonized iron.

The gas furnace may be of any desired capacity, or two or more such furnaces may be used together in making large castings.

In cases where transportation of castings from blast furnaces to market would be inconvenient or too expensive, I obtain some of the advantages of the foregoing process as follows:—I combine with one or more reverberatory or gas furnaces one or more cupola furnaces, so arranged that the metal melted in the cupolas can be tapped and run into the other furnaces and from the latter into
1374 moulds or into ladles for being poured into moulds. In such cases I use the cupola furnaces for melting pig iron, and I prefer to melt therein the most inferior metal to be used, and also all metal the character whereof is not definitely known. The iron so melted will then be tapped into the gas or other furnaces, and samples taken therefrom and tested, and thereupon it can be treated in any way to give it the desired qualities for any kind of casting.

It will be understood that the character of the iron in the gas furnaces can be varied from time to time or kept continuously at one standard, and not only by this means may any desired uniformity or variety in the quality of castings produced be attainable, but greater economy in cost; because by this plan cheaper mixtures of pig iron can be made for any given purpose than can be made in cupolas, and such mixtures can be more quickly and cheaply made than they can be by the use of the gas or reverberatory furnaces alone.

I am aware that it is not new to run or pour crude iron from blast furnaces into reverberatory furnaces for the purpose of puddling or refining it for being puddled or otherwise treated for the manufacture of malleable iron and steel, and I make no claim thereto.

Having thus described the nature of this invention, and in what manner the same is to be performed, as communicated to me by my foreign correspondent, what I claim is,—

First. Combining converting vessels with reverberatory furnaces and blast or smelting furnaces in such wise as that the crude iron can be tapped and run or carried, raised, and poured from the blast furnaces into the reverberatory furnaces, and then, after being treated as may be desired, be tapped out and run into converters, substantially as and for the purposes described and specified.

Second. Combining converting vessels with reverberatory furnaces and cupola furnaces, in such wise as that the metal melted in

the cupola furnaces can be run from thence into the reverberatory furnaces, and from the latter to the converters, substantially as and for the purposes described and specified.

Third. The herein-described modes of producing uniformity in the character of the iron to be converted by the pneumatic or Bessemer process.

1375 Fourth. So combining the apparatus used in the conversion of crude iron by the pneumatic or Bessemer process that the metal under treatment in the converters can be poured out and transferred to a reverberatory furnace and then tapped back into the converters, substantially for the purposes specified.

Fifth. The herein-described modes of treating iron for the manufacture of castings by first producing it in blast furnaces or melting it in ordinary cupola furnaces, and then, previously to founding it tapping it into reverberatory furnaces and refining it, or in otherwise modifying its character.

Sixth. Combining reverberatory or gas melting furnaces with blast furnaces or cupola furnaces for treating iron for the manufacture of castings, substantially as herein described.

In witness whereof, I, the said Charles Denton Abel, have hereunto set my hand and seal, this third day of September, in the year of our Lord one thousand eight hundred and seventy-two.

CHAS. D. ABEL. [L. S.]

London: Printed by George Edward Eyre and William Spottiswoode, printers to the Queen's most excellent majesty. 1872.

1376 [British coat of arms.]

A. D. 1873, 11th November. No. 3672.

Manufacture of Bessemer Steel.

Letters patent to William Deighton, of Workington, in the county of Cumberland, designer, draughtsman, and roll turner, for the invention of "improvements in the arrangement and mode of working of apparatus for the manufacture of Bessemer steel."

Sealed the 20th January, 1874, and dated the 11th November, 1873.

Provisional specification left by the said William Deighton at the office of the commissioners of patents, with his petition, on the 11th November, 1873.

I, William Deighton, of Workington, in the county of Cumberland, designer, draughtsman, and roll turner, do hereby declare the nature of the said invention for "improvements in the arrangement and mode of working of apparatus for the manufacture of Bessemer steel," to be as follows:

In manufacturing Bessemer steel by apparatus arranged and worked in the ordinary manner time is lost while working
1377 and expensive plant is inoperative, and much time is lost while the "converters" are being cooled and relined or repaired and again prepared for work, such relining being required very frequently, and the object of my invention is to economise the time now lost in working and repairing by such arrangement and mode of working as will keep the plant or apparatus in nearly uninterrupted work, and thus very considerably increasing the production with a plant of comparatively little cost, at the same time effecting a great saving of labour.

My invention consists in the arrangements and mode of working described as follows: The "converters" are constructed and arranged in the ordinary manner with all the gearing for operating them, but the "converting vessel" itself is so arranged that it can be readily detached from its actuating mechanism, and lifted bodily out of its bearings by a suitable crane or other lifting mechanism, and I have at least two spare converting vessels, which when not in use are placed with their trunnions in pedestals in suitable frames or stands.

When a converter requires "relining" or repair I lift it by means of a crane or other mechanism directly from the pedestals in which it works, and deposit it in a suitable tank full of water to cool, and then immediately lift one of the spare converters which has been prepared and made ready for use into the proper working pedestals of the converter, and then fill in the molten metal from

the cupola furnace, so that very little time is lost in effecting the change.

When the converter which has been placed in the water tank has cooled sufficiently it is lifted out and placed upon one of the aforesaid framings or stands, where it can be relined and repaired, then fuel is placed in it and lighted, and a blast of air from a fan is turned into it, so that it will be heated up ready to take the place of the converter then at work when it requires relining or repair. I prefer to place the cupolas which supply the "converter" with molten metal in a row or line parallel to the axis upon which the converter turns, the converter turning towards the cupolas when the molten steel is to be poured into the ladle, which I prefer to suspend from a travelling crane or other lifting and travelling mechanism, such ladle being then carried by the travelling mechanism to any convenient part of the building for running the metal into moulds to form ingots or castings.

1378 When the converter has been emptied a fresh supply of molten metal is run into it from the cupola or cupolas down a swivel trough in the ordinary manner.

Specification in pursuance of the conditions of the letters patent filed by the said William Deighton in the Great Seal patent office on the 7th May, 1874.

To all to whom these presents shall come I, William Deighton, of Workington, in the county of Cumberland, designer, draughtsman, and roll turner, send greeting:

Whereas Her Most Excellent Majesty Queen Victoria, by her letters patent, bearing date the eleventh day of November, in the year of our Lord one thousand eight hundred and seventy-three, in the thirty-seventh year of her reign, did, for herself, her heirs and successors, give and grant unto me, the said William Deighton, her special license that I, the said William Deighton, my executors, administrators, and assigns, or such others as I, the said William Deighton, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel islands, and isle of Man, an invention for "improvements in the arrangement and mode of working of apparatus for the manufacture of Bessemer steel," upon the condition (amongst others) that I, the said William Deighton, by an instrument in writing, under my hand and seal, should particularly describe and ascertain the nature of the said invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal patent office within six calendar months next and immediately after the date of the said letters patent.

Now know ye, that I, the said William Deighton, do hereby declare the nature of my said invention, and in what manner the same is to be performed, to be particularly described and ascertained

in and by the following statement, and the accompanying drawings (that is to say):—

In manufacturing Bessemer *sheet* by apparatus arranged and worked in the ordinary manner time is lost while working,
1379 and expensive plant is inoperative, and much time is lost while the converters are being cooled and relined or repaired and again prepared for work, such repairs being required very frequently, and the object of my invention is to economise the time now lost in working and repairing by such arrangement and mode of working as will keep the plant or apparatus in nearly uninterrupted work, thus very considerably increasing production with a "plant" of comparatively little cost, at the same time effecting a great saving of labor.

My invention consists in the arrangements and mode of working described as follows:—The converters are constructed and arranged in the ordinary manner with all the gearing for operating them, but the converting vessel itself is so arranged that it can be readily detached from its actuating mechanism and lifted bodily out of its bearings by a suitable crane or other lifting mechanism, and I have at least two spare converting vessels, which when not in use are placed with their trunnions in pedestals in suitable frames or stands.

When a converter requires relining or repair I lift it by means of a crane or other mechanism directly from the pedestals in which it works, and deposit it in a suitable tank full of water to cool or to be acted upon by other cooling arrangements, or it may be placed in a stand and allowed to cool in the atmosphere simply, and then I immediately lift one of the spare converters which has been prepared and made ready for use into the proper working pedestals of the converter, and then fill in the molten metal from the cupolo furnace or from the blast furnace, as hereinafter more fully explained, so that very little time is lost in effecting the change.

When the converter *which* has been placed in the tank of water, or has been otherwise cooled sufficiently, it is lifted out and placed upon one of the aforesaid framings or stands, where it can be relined and repaired, then fuel is placed in it and lighted, and a blast of air from a fan or other mechanism is turned into it, so that it will be heated up ready to take the place of the converter then at work when it requires relining or repair. I prefer to place the cupolas which supply the converter with molten metal in a row or line parallel to the axis upon which the converter turns, the converter turning towards the cupolas when the molten steel or
1380 metal is to be poured into the ladle, which I prefer to suspend from a travelling crane or other lifting and travelling mechanism, such ladle being then carried by the travelling mechanism to any convenient part of the building for running the metal into iron moulds to form ingots.

When the converter has been emptied a fresh supply of molten metal is run into it from the cupola or cupolas down a swivel trough in the ordinary manner.

Instead of manufacturing Bessemer iron or steel from pig iron

FOLDOUT(S) IS/ARE TOO LARGE TO BE FILMED

which has to be melted in cupolas my invention also consists in taking the molten metal directly from the blast furnace to the converter, in which case I prefer to arrange the Bessemer plant in a line at a right angle to a row of two of more blast furnaces, and place a vessel to receive the molten metal tapped from two or more blast furnaces to get a better average of metal which will be more suitable for making Bessemer steel or metal of uniform quality, the vessel or receiver being placed on a weighing machine so that any required weight may be drawn or tapped from it and charged into the converter.

Instead of lifting the co-verters from their position when in use by a travelling crane, each converting vessel may be mounted on a wheeled carriage to run on a railway, and by means of one or more turntables the converters could be brought opposite to and connected with the blast pipe and the gearing for turning them upon their trunnions, and removed when requiring to be repaired, and there might be so many spare converters as would be required to give time to cool them naturally, or they might be cooled by a rain bath formed by a great number of fine jets of water on all sides and within the converter acting simultaneously upon it, or by envelope or casing lowered over the converter and its carriage, in which steam, vapour, and spray could be injected so as to act upon all parts of it at the same time.

In place of the travelling crane to lift and carry the ladle with the molten metal from the converter the ladle may be mounted in the ordinary manner, the central axis being carried on a frame having wheels to run on a railway, but I prefer to use a travelling crane for lifting and carrying the converters and ladles, as hereinbefore described.

(Here follows diagram marked p. 1384.)

Fig. 1 is a plan and Fig. 2 a sectional elevation upon the line A, B, Fig. 1, shewing my improved arrangement of plant for
1381 the manufacture of Bessemer metal from pig iron. *a* is the converter with its gearing for turning and arrangements for the air blast, as usual, except that the caps of the pedestals for the trunnions are hinged so as to be quickly removed when the converter is to be lifted out of them, and the trunnion for the blast is arranged so as to be readily connected or disconnected with the blast pipe by any suitable arrangement, such as a sliding double packing box, see Fig. 3, in which *b* represents the trunnion of the converter; *c*, the blast pipe; *d*, the sliding box, having two recesses for packing rings like those for the rams of hydraulic presses. When the box is slided entirely on the end of the pipe *c* the converter can be removed, but when the sliding box is in the position shown in Fig. 3 the connection is complete between the blast pipe and converter. a^1, a^2, are spare converting vessels placed on stands *e*, and arranged so as to be readily connected with a blast pipe *f* when the fire is lighted in them and they are to be heated up ready for use. *i* is the cistern or vessel in which the converters are placed

to be cooled; *h* are three cupola furnaces for melting the pig iron; and *i* are the cupola furnaces for the spe*i*gel eisen. From each cupola there is a channel which leads to a swivel trough *j*, which reaches to the mouth of the converter (*a*) when turned into the position in which it is shewn in Fig. 2. *k* is the crane of ordinary construction, which travels on rails carried by one beam secured to the side wall on one side, and another beam mounted on columns. This crane will lift and move the ladle *l* for the molten metal, and lift and carry the converters when required.

Fig. 4 is a plan and Fig. 5 sectional elevation on the line C, D, Fig. 4, shewing my improved arrangement of plant for manufacturing Bessemer metal directly from the smelting furnace, *a* is the converter in its position when in use, which converter is capable of being readily lifted from its pedestals and disconnected with the blast pipe *c*, as hereinbefore described. a^1, a^2, are the spare converters in stands *e*, under repair, or in preparation for use, as before explained; *g*, the water tank for cooling the converters; *i* are cupolas for the spe*i*gel eisen; *j*, swivel spout for conveying the molten spe*i*gel eisen from the cupolas to the converter; x^2, x^3, shows the position of two smelting furnaces, Nos. 2 and 3, and two other furnaces are supposed to be in the same line, one by the side of No. 2, and the other by the side of No. 3 furnace; y^1, y^2, y^3, y^4, are gates or channels from the molten metal from each furnace, which
1382 channels lead to a receiving vessel *m*, which is placed low enough to give fall for the molten metal to flow from the blast furnaces to this receiver *m*, which forms a receptacle for mixing the molten metals from two or more of the smelting furnaces. From the receiver *m* the mixed molten metal is tapped, and flows down the swivel trough *n* into the converter (*a*). By placing the vessel *m* on a weighing machine it can be readily ascertained when the exact quantity required has been tapped from it into the converter. When the vessel *m* requires repair it is replaced by another kept ready for use. When from any cause the converters are not at work the metal from the blast furnaces can be run into pigs, the space (*q*) on each side of the building for the converters being formed into casting beds. Fig. 5 shows the railway (*p*) for the traveling crane (*k*) the beams for which are carried on the side walls W, shown in Fig. 4.

I have now particularly described the nature of my invention, and the mode of carrying the same into effect, and claim as my invention,—

Firstly. The system or mode of arranging and working Bessemer plant by which there are one, two, or more spare converting vessels, so that the vessel in use may be readily removed from its pedestals or working position and replaced by one of the spare vessels which has been repaired and heated ready for use, substantially as hereinbefore described.

Secondly. The system or mode of working whereby the converter is taken from its working position to a stand or other suitable position to be cooled, repaired, or relined, and prepared for use, or to a tank of water or other position where it can be acted upon to pro-

mote rapid cooling by steam, rain bath, or spray, and then repaired, relined, and prepared for use substantially as hereinbefore described.

Thirdly. The use and arrangement of a travelling crane for lifting and carrying the ladle in which the molten metal from the converter is poured to the ingot moulds, substantially as hereinbefore described.

Fourthly. The arrangement of the cupolas (*h*), the converting vessel (*a*), and the spare converting vessels a^1, a^2, and water or cooling tank (*g*), and travelling crane *k*, substantially as herein-before described and illustrated by Figs 1 and 2 of the drawings.

Fifthly. The system or mode of arranging and working Bessemer plant in connection with one, two, or more blast or smelting
1383 furnaces, substantially as herein before described and illustrated by Figs. 4 and 5 of the drawings.

Sixthly. The system or mode of arranging and working Bessemer converters with a receiver or receptacle (*m*) for mixing the molten metal from two or more smelting furnaces to get a more uniform quality of metal, substantially as hereinbefore described and illustrated by the drawings.

In witness whereof, I, the said William Deighton, have hereunto set my hand and seal, this thirtieth day of April, in the year of our Lord one thousand eight hundred and seventy-four.

WILLIAM DEIGHTON. [L. S.]

London: Printed by George Edward Eyre and William Spottiswoode, printers to the Queen's most excellent majesty. 1874.

1385 [British coat of arms.]

A. D. 1877, 28th December. No. 4920.

Furnaces for the Manufacture of Iron and Steel.

Letters patent to Alfred Longsdon, of Queen Victoria street, in the city of London, engineer, for the invention of "improvements in furnaces for the manufacture of iron and steel by the application of a combined reverberatory and Bessemer furnace." A communication from abroad by Alfred Krupp, of Essen, in the Empire of Germany.

Sealed the 28th February, 1878, and dated the 28th December, 1877.

Provisional specification left by the said Alfred Longsdon at the office of the commissioners of patents on the 28th December, 1877.

ALFRED LONGSDON, of Queen Victoria street, in the city of London, engineer.

"Improvements in furnaces for the manufacture of iron and steel by the application of a combined reverberatory and Bessemer furnace." (A communication from abroad by Alfred Krupp, of Essen, in the Empire of Germany.)

The object of this invention is to apply one and the same furnace as a reverberatory and Bessemer furnace, so that when in one position it may be used as a reverberatory furnace; and when in another position as a Bessemer furnace, whereby the charge may be treated as in a reverberatory furnace, or have air blown through it as in a Bessemer furnace; the operations may be carried on alternately as desired.

A convenient way to carry the invention into effect of combining a reverberatory furnace with a Bessemer furnace is as follows:—The body proper of the furnace can revolve on its longitudinal axis, and is provided with Bessemer twyeres on one narrow side of its oval section. A Siemens' regenerator may be used for reheating, but any other arrangement for reheating may be used.

When the furnace is in a horizontal position the heating gases flow alternately on one side of the furnace from apertures of the regenerator chambers into orifices of the apparatus proper, and after having passed through the same they pass off through openings on the opposite side of the apparatus, and there re-enter the regenerator chambers on that side.

1386 When the furnace is turned into a vertical position the inlet valve of the blast is open by an eccentric during this rotation, and air is admitted into the twyere chambers by a pipe,

and then through twyeres into the fluid metal. The body of the furnace is sustained by or rests on rings, which rest on friction rollers, one of the said rollers and the ring forming the pinion and wheel, whereby the furnace is rotated. The supporting and driving portions of the apparatus being combined in this way, the wheels are well geared, even should the furnace twist, and the large tooth wheel get out of truth. The axle of the pinion roller carries a worm wheel at its other end in gear with worm driven from any suitable prime mover.

Charging and discharging of the furnace are effected through a mouth opposite the twyeres; this mouth is closed by door during heating. The furnace proper is mounted on a carriage, so that it can be easily replaced by another, in case of necessity, without putting the generator or other fire out of work. The reheating of the charge takes place on a flat hearth, and no part of the charge is left in the apparatus after tapping, as is the case ordinarily when a very flat fixed hearth with tapping hole is used.

When the apparatus is in a vertical position the Bessemer process can proceed without injury to the regenerator chambers, as they are shut off from the furnace proper by the openings thereto being closed through the position of the furnace.

The above-described combined reverberatory and Bessemer furnace enables the Bessemer process to be worked with such sorts of pig iron, the working of which is too cold in an ordinary Bessemer converter, especially with the much cheaper white pig iron and pig iron purified according to what is known as "Krupp's" method.

By the use, too, of furnaces constructed according to this invention, large quantities of steel and wrought iron scraps can be added to the pig iron and a "dead" melted metal is obtained; by reheating the metal again after the Bessemer process has taken place, the physical properties are improved, and the chemical properties can also be improved by any desired additions, and all this is attained in and by the same apparatus, reheating the charge or blowing air through it alternately at will. The white pig iron, for instance, melted in any other furnace, is charged into the apparatus when in the upright position through the mouth, then it is first superheated, and in the apparatus, when upright, turned into Bessemer metal. Then the charge is reheated in the apparatus placed horizontally, scraps being added at will, thus obtaining a "dead" melted metal, and by means of suitable additions the ordinary Bessemer metal is improved to a higher quality.

A combined reverberatory and Bessemer furnace may be used, similar to an ordinary Bessemer converter, but flattened, and with a broad opening or mouth through which the apparatus is heated by the injection of pulverized coal, such as is now known as Crampton's system, or other arrangements for the supply of powdered fuel may be used, or the system known as Siemens' for his rotators may be used. Supply of blast and movement of the converter as before. Air enters by a pipe into a series of twyere chambers extending over the full width of the converter and from there into the twyeres. Sometimes a narrower mouth is employed and double

bottom; then when the Bessemer process takes place both bottoms receive (separated from one another) air through both converter trunnions; but in turning the apparatus into the horizontal position for reheating the charge, the air in the lower bottom is self-actingly replaced by lighting gas injected under pressure by steam. The upper bottom receives air as before, but now it is used for combustion of the gas, or it may be that the flame would not strike back into the bottom if a single one were employed, and the lighted gas were injected directly through the twyere blast.

When the apparatus is heated the burnt gases escape by a flue.

1387 Specification in pursuance of the conditions of the letters patent filed by the said Alfred Longsdon in the Great Seal patent office on the 28th June, 1878.

ALFRED LONGSDON, of Queen Victoria street, in the city of London, engineer.

"Improvements in furnaces for the manufacture of iron and steel by the application of a combined reverberatory and Bessemer furnace." (A communication from abroad by Alfred Krupp, of Essen, in the Empire of Germany.)

The object of this invention is to apply one and the same furnace as a reverberatory and Bessemer furnace, so that when in one position it may be used as a reverberatory furnace, and when in another position as a Bessemer furnace, whereby the charge may be treated as in a reverberatory furnace, or have air blown through it as in a Bessemer furnace, the operations may be carried on alternately as desired.

A convenient way to carry the invention into effect is as follows:—The body proper of the furnace can revolve on its longitudinal axis, and is provided with Bessemer tuyeres on one narrow side of its oval section. A Siemens' regenerator may be used for re-heating, but any other arrangement for re-heating may be employed.

When the furnace is in a horizontal position the heating gases flow alternately on one side of the furnace from apertures of the regenerator chambers into orifices of the apparatus proper, and after having passed through the same they pass off through openings on the same or opposite side of the apparatus, and there re-enter the regenerator chambers on that side.

When the furnace is turned into a vertical position the inlet valve of the blast is opened by an eccentric during this rotation, and air is admitted into the tuyere chambers by a pipe, and then through tuyeres into the fluid metal. The body of the furnace is sustained by or rests on rings which rest on friction rollers, one of the said rollers and the ring forming the pinion and wheel, whereby the furnace is rotated. The supporting and driving portions of the apparatus being combined in this way, the wheels are well geared, even should the furnace twist and the large toothed wheel get out of truth. The axle of the pinion roller carries a worm wheel at its other end in gear with worm driven from any suitable prime mover,

FOLDOUT(S) IS/ARE TOO LARGE TO BE FILMED

or motion may be transmitted thereupon by spur wheel or other gearing.

Charging and discharging of the furnace are effected through a mouth opposite the tuyeres; this mouth is closed by door during heating. The furnace proper is mounted on a carriage, so that it can be easily replaced by another in case of necessity, without putting the generator or other fire out of work. The re-heating of the charge takes place on a flat hearth, and no part of the charge is left in the apparatus after tapping, as is the case ordinarily when a very flat fixed hearth with tapping hole is used.

When the apparatus is in a vertical position, the Bessemer process can proceed without injury to the regenerator chambers, as they are shut off from the furnace proper by the openings thereto being closed through the position of the furnace or by special doors.

On the accompanying sheets of drawings I have shown apparatus suitable for carrying this invention into effect.

(Here follow diagrams marked pp. 1390, 1391, & 1392.)

Figures 1 and 3, sheet 1, and figures 6, 7, and 8, sheet 3, show the apparatus in the position required for the Bessemer part of the process; and figure 2, sheet 1, figures 4 and 5, sheet II, and figures 9, 10, 11, sheet III, show the same apparatus in the position required for the re-heating part of the process. As before stated the heating of the furnace may be effected by a gas regenerator furnace as supposed in this case, or by any other suitable heating appliance.

Figures 6 and 7, sheet III, and figures 1 and 3, sheet I, are respectively vertical longitudinal section and vertical transverse section through the furnace, constructed and adapted for this process; and figure 8, sheet III, is an outside end view of the apparatus proper, and a section through line M, L, figure 6, as regards the parts below the same.

1388

Figures 9, 10, and 11, sheet III, are respectively vertical longitudinal section, vertical transverse section, and horizontal longitudinal section through the apparatus proper.

The body *a* of the furnace or converter, sheet III, is at its ends provided with hollow pivots *b* and *c*, which rest on friction rollers *d*, and are held down against them by the weight of the apparatus itself, and by a cap and tie bolts as shewn. The apparatus is turned into the required positions by wheel gearing *e* at the end of the pivot *b*, the said gearing being actuated from a steam engine *f*, the fly wheel *g* of which is provided with a brake.

The charge contained in the furnace is when in the position shewn in figures 9, 10, and 11, sheet III, heated by the two openings *l*, *l*, (which openings during the Bessemer part of the process are closed by means of doors *q*, shewn in position on figure 6, sheet III); *m* is the throat or exit opening of the converter; this opening is closed by a door or cover *r*, figure 11, during the re-heating part of the process; the opening *m* serves for charging and discharging the apparatus; or an opening *z*, as shewn in dotted lines in figure 7, may be applied for discharging, in order to keep back all the slag.

The blast in the Bessemer part of the process enters from the pipe *h*, figure 6, sheet III, by a self-acting valve in the upper part thereof in the usual manner, passing through the pivot *c* into the pipe *i*, and thence to the three branch pipes i^1 and tuyeres *k*.

The openings *l*, Figs. 9, 10, and 11, sheet III, in the re-heating part of the process receive the heating gases from the corresponding openings *o* in the head *n* of the regenerator furnace. The openings *o* are closed by doors *p*, figures 10 and 8, sheet III, during the Bessemer part of the process, and the heat from the gas furnace is thus shut off during that time.

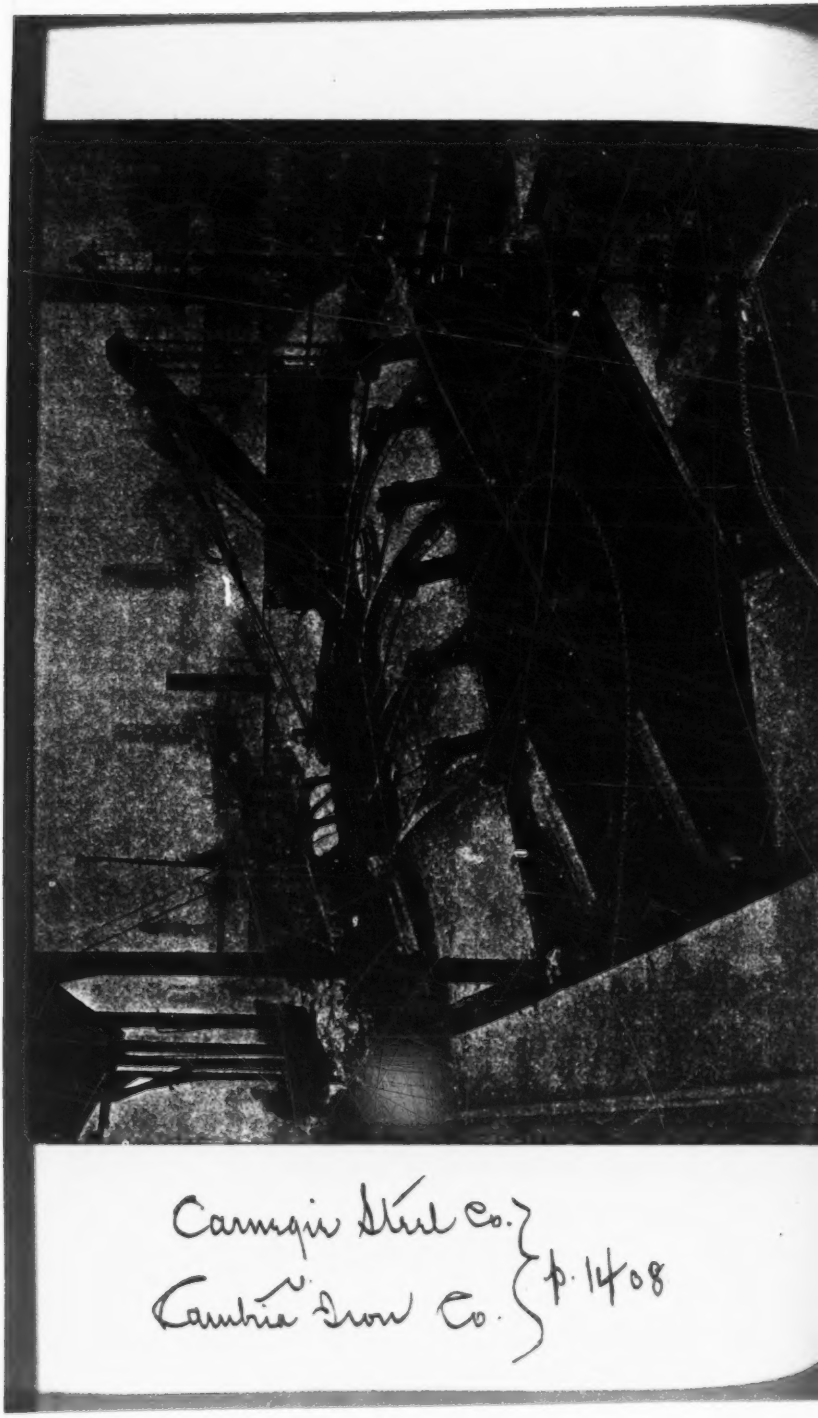
The furnaces may be arranged in couples with one common gas-heating furnace, as indicated on figure 8, where the space marked a^1 on the right of the centre line is supposed to be occupied by a furnace similar to *a* on the left; the heat for the furnace at a^1 comes from the opening o^1. In such an arrangement an alternate working may be applied, one Bessemer apparatus being at work while the lining of the other is cooling down and being repaired.

The above-described combined reverberatory and Bessemer furnace enables the Bessemer process to be worked with such sorts of pig iron, the working of which is too cold in an ordinary Bessemer converter, especially with the much cheaper white pig iron and pig iron purified according to what is known as "Krupp's" method. By the use too of furnaces constructed according to this invention, large quantities of steel and wrought iron scraps can be added to the pig iron, and a "dead" melted metal is obtained by re-heating the metal again after the Bessemer process has taken place; the physical properties are improved, and as the chemical properties can also be improved by any desired additions; and all this is attained in and by the same apparatus reheating the charge or blowing air through it alternately at will. The white pig iron, for instance, melted in any other furnace, is charged into the apparatus *a* when in the horizontal position through the mouth *m*, then it is first superheated, and in the apparatus when upright, as shewn in figures 6, 7, and 8, sheet III, turned into Bessemer metal. Then the charge is re-heated in the apparatus placed horizontally, as shewn in figures 9, 10, and 11, sheet III, scraps being added at will, thus obtaining a "dead" melted metal, and by means of suitable additions the ordinary Bessemer metal is improved to a higher quality.

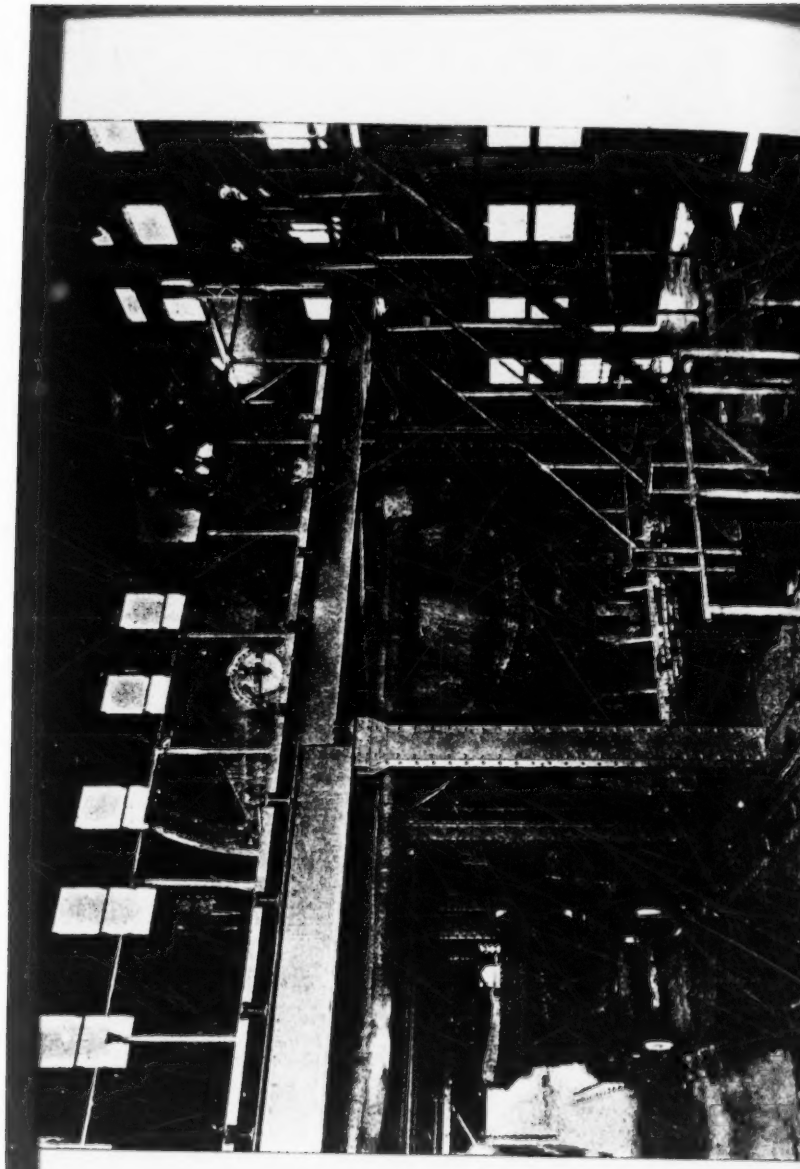
A combined reverberatory and Bessemer furnace may be used similar to an ordinary Bessemer converter, but flattened, and with a broad opening or mouth through which the apparatus is heated by the injection of pulverized coal, such as is now known as
1389 Crampton's system, or other arrangements for the supply of powdered fuel may be used, or the system known as Siemens' for his rotators may be used, supply of blast and movement of the converter being effected as before. Air enters by a pipe into a series of tuyere chambers, extending over the full width of the converter, and from there into the tuyeres. Sometimes a narrower mouth is employed and double bottoms, then when the Bessemer process takes place both bottoms receive (separated from one another) air through both converter trunnions, but in turning the apparatus into the

FOLDOUT(S) IS/ARE TOO LARGE TO BE FILM

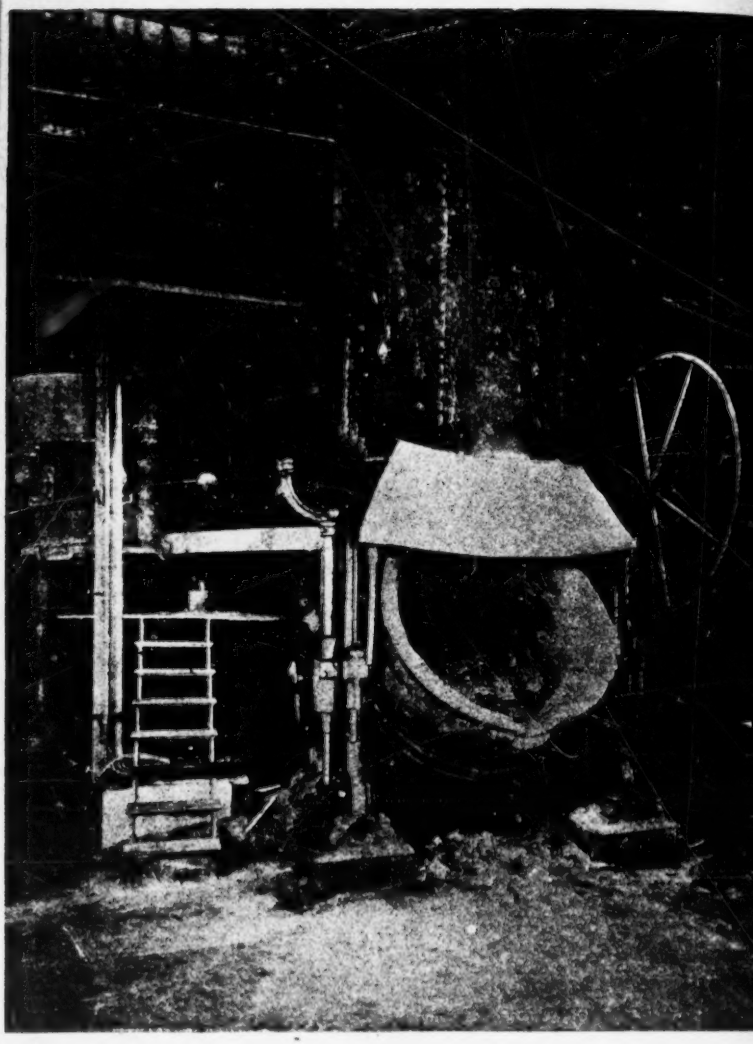
Carnegie Steel Co.
v.
Cambria Iron Co. } p. 1107.



Carnegie Steel Co.
Cambria Iron Co. } p. 1408

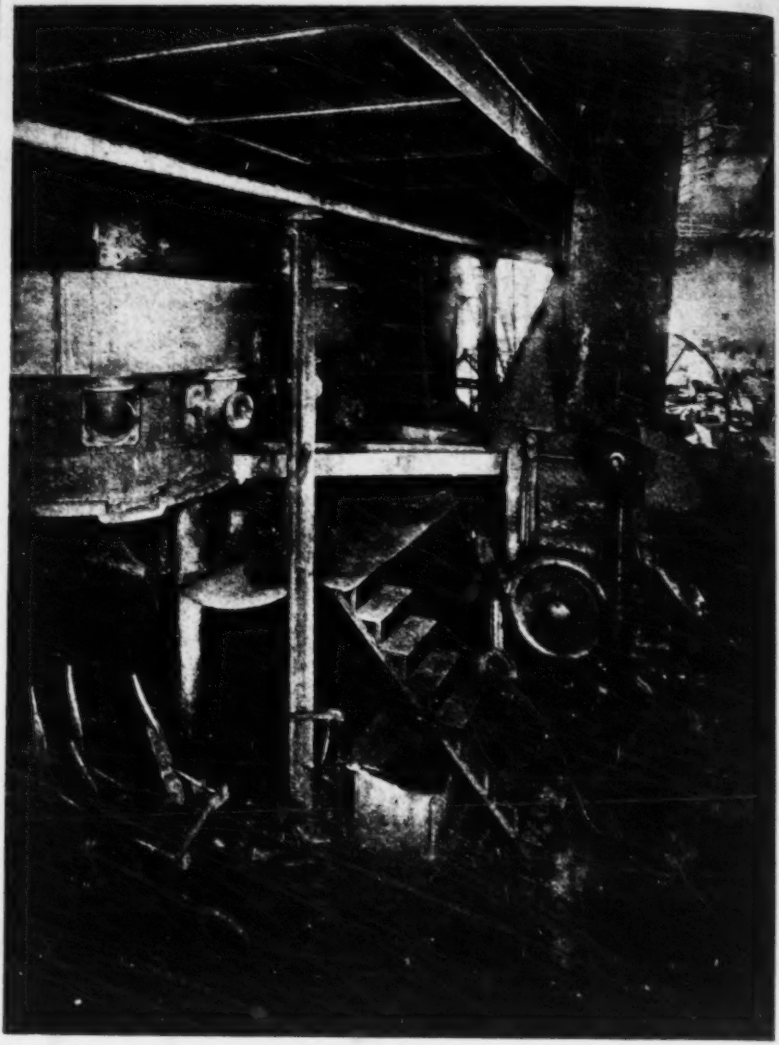


Carnegie Steel Co.
v.
Cambria Iron Co. } #1409



Complainant's Exhibit Photograph Whitney Cupolas, Sheet 1.

Carnegie Steel Co
v.
Cambria Iron Co.
} B. 11/10



Complainant's Exhibit Photograph Whitney Cupolas, Sheet 2.

Carnegie Steel Co.
v.
Cambria Iron Co.
} P. 11/11

horizontal position for reheating the charge of the air in the lower bottom is self-actingly replaced by lighting gas injected under pressure by steam. The upper bottom receives air as before, but now it is used for combustion of the gas, or it may be that the flame would not strike back into the bottom if a single one were employed and the lighted gas were injected directly through the tuyere blast.

When the apparatus is heated the burnt gases escape by a flue.

And having thus described and ascertained the nature of this invention, I declare that I claim,—

Firstly. The application of apparatus consisting of a combined reverberatory and Bessemer furnace for alternately heating the charge and blowing air through it, substantially as set forth.

Secondly. The construction and application of apparatus operating as herein described and shewn, consisting of an oval Bessemer converter, which can turn on its longitudinal axis, and which is provided on one narrow side with Bessemer tuyeres, and on the other narrow side with opening for the admission of heat.

In witness whereof, I, the said Alfred Longsdon, have hereunto set my hand and seal, this seventeenth day of June, in the year of our Lord one thousand eight hundred and seventy-eight.

ALFRED LONGSDON. [L. S.]

London: Printed by George Edward Eyre and William Spottiswoode, printers to the Queen's most excellent majesty. For Her Majesty's stationery office. 1878.

(Here follow diagrams marked pp. 1393 to 1411, inclusive.)

1412 *Metal Mixer Analyses Made of Every Other Tap, January, '93–April, '94.*

The Carnegie Steel Company, Limited.

Laboratory of the Edgar Thomson Steel Works.

Analyses of iron from mixers.

FROM 8 A. M. 5-31 TO 8 A. M. 6-1. BESSEMER, JUNE 1, 1893.

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
4922	8.00 A. M.	.91		
24	8.40	.96	.028	.81
26	9.30	.93		
28	No test taken.			
30	10.20	1.33	.028	.91
32	10.55	1.35		
34	11.40	1.21	.018	.92
36	12.15	1.31		
38	12.45	1.24	.032	.61
40	1.10	1.26		
42	1.55	1.07	.038	.72
44	2.25	1.14		
46	3.00	1.05	.038	.67
48	3.15	1.19		
50	4.00	1.26	.040	1.01
52	4.20	1.33		
54	5.00	1.19	.038	.90
56	5.30	.93		
59	6.15	.79	.048	.95
61	7.10	.79		
63	7.45	.77	.050	.80
65	8.45	.79		
67	9.15	.70	.056	.75
69	10.00	.79		
71	10.35	.98	.040	.82
73	11.10	.84		
75	No test.			
77	12.20	.93	.040	.84
79	12.50	.61		
81	1.20	.98	.032	.90
83	1.55	.93		
86	2.40	.84	.040	.94
88	3.30	1.02		
91	4.20	1.12	.036	.74
93	4.50	1.16		
95	5.20	1.07	.040	.80
97	5.45	.89		
5000	7.40	1.17	.050	.71

1413

FROM 8 A. M. 6-1 TO 8 A. M. 6-2. BESSEMER, JUNE 2, 1893.

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
5002	8.25 A. M.	.89		
4	8.55	.96	.026	.86
6	9.30	1.10		
8	10.00	1.03	.044	.77
10	10.30	.79		
12	10.55	.84	.042	.55
14	11.25	.70		
16	No test.			
18	12.55	.75	.057	.71
20	1.30	.84		
22	1.50	.84	.035	.53
24	2.30	.91		
26	3.00	.89	.026	.60
28	3.25	.84		
30	3.55	.89	.035	.81
32	4.20	1.12		
34	4.45	1.05	.033	.79
36	5.10	.96		
38	No test.			
40	6.25	1.03	.026	.77
42	6.50	.89		
44	7.20	.91	.030	.76
46	7.50	1.07		
48	8.20	1.10	.037	.91
50	8.50	.84		
52	9.50	1.17	.035	.80
54	10.20	1.30		
56	10.40	1.21	.024	.93
58	11.10	1.12		
59	11.25	1.02	.031	.88
61	11.55	.96		
63	12.40	.96	.026	.82
65	1.30	1.07		
67	1.50	1.30	.031	
69	2.20	1.26		
71	2.50	1.07	.035	.79
73	3.40	1.12		
74	4.15	1.21	.042	.91
77	5.05	1.12		
80	5.30	1.03	.031	.83
82	No test taken.			
84	" "			
86	7.15	1.17		
88	7.50	.91	.040	

1414

FROM 8 A. M. 6-2 TO 8 A. M. 6-3. BESSEMER, JUNE 3, 1893.

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
5090	8.15 A. M.	.93		
92	9.05	.70	.038	.81
95	9.45	.70		
97	10.10	.93	.024	.90
99	10.40	1.12		
5101	11.15	.75	.022	.74
3	11.40	.81		
5	No test taken.			
7	12.30	1.14	.022	.71
9	12.50	1.00		
11	1.20	.86	.032	.80
13	No test taken.			
15	2.40	.96		
17	3.15	.65	.038	.80
18	3.40	.89		
20	3.55	.61	.026	.94
23	4.40	.68		
24	5.00	.58	.034	.70
26	5.10	.56		
28	5.25	.61	.040	.79
33	6.40	.84		
34	7.10	.79	.044	{ 1.03 { 1.05
36	7.35	.82		
38	8.00	.75	.038	1.01
40	8.25	1.03		
42	8.45	.82	.040	.99
44	9.20	.93		
46	10.00	.65	.034	.61
48	10.45	.68		
51	11.45	.51	.044	.71
56	12.30 A. M.	.75		
58	1.05	.93	.036	.76
60	1.35	.84		
63	1.50	.89	.042	.91
65	No test.			
67	3.05	1.02		
69	3.50	.79	0.40	.70
71	4.10	.98		
73	4.40	1.07	.018	.87
75	5.10	.93		
78	6.55	.89	.040	
80	7.20	.75		

1415

FROM 8 A. M. 6-3 TO 8 A. M. 6-5. BESSEMER, JUNE 5, 1893.

	Blow No.	Time.	Silicon.	Sulphur.	Manganese.
6-3	5182	8.05 A. M.	.84	.038	.84
	84	8.40	.70		
	86	9.40	.75	.038	.71
	88	10.05	.84		
	90	10.30	.86	.044	.72
	92	10.55	.91		
Direct iron.					
6-4	99	6.30 P. M.	1.07		
	5201	6.55	1.07	.042	.80
	4	7.10	.93		
	6	8.05	.79	.044	.61
	7	8.20	.86		
	10	9.00	1.00	.040	.83
	13	9.20	1.24		
	14	11.20	1.21	.024	.90
	16	11.45	1.17		
6-5	18	1.10 A. M.	1.00	.026	.91
	20	1.50	.98		
	22	2.10	.98	.030	.87
	25	2.25	.91		
	27	3.20	1.00	.032	
	28	3.45	1.05		
	30	4.00	1.00	.024	1.02
	32	4.45	.96		
	34	No test.			
	36	No test.			
	38	6.30 A. M.	.75	.032	1.08
	5240	6.55 A. M.	.93		
	42	7.45	.89	.036	

FROM 8 A. M. 6-5 TO 8 A. M. 6-6. BESSEMER, JUNE 6, 1893.

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
5244	8.05 A. M.	1.02	....	1.03
46	8.40	1.26	.030	
48	9.10	1.12	....	1.07
50	9.45	1.07	.044	1.09
52	10.10	1.12		
53	No test.			
55	11.15	.98	.031	1.08
57	No test.			
59	No test.			
60	12.25 P. M.	.93		
62	12.45	1.07	.044	.94
64	1.15	1.16		
68	1.55	1.16	.044	.97

1416

	Blow No.	Time.	Silicon.	Sulphur.	Manganese.
	70	2.25	1.30		
	73	3.20	1.26	.040	
	75	3.40	1.19		
	77	4.06	1.05	.028	.97
	79	4.30	1.03		
	81	4.55	1.03	.038	.93
	83	5.34	1.00		
	85	No test.			
	87	6.20	1.10	.036	.94
	89	6.50	1.26		
	91	7.15	1.17	.036	.97
	92	7.40	1.14		
	95	8.15	1.17	.032	.90
	97	8.55	1.14		
	99	9.20	1.12	.032	.84
	5301	9.40	.86		
	3	10.10	.72	.034	.76
	5	10.40	1.07		
	7	11.05	.75	.052	
	9	11.30	.84		
	11	12 M.	1.21	.038	.87
	13	No test.			
6–6	15	12.40 A. M.	1.05		
	17	1.15	.93	.050	.90
	19	1.35	1.26		
	21	1.50	1.21	.032	1.04
	23	2.05	.86		
	25	2.30	.93	.036	.81
	27	2.55	1.05		
	29	3.20	1.12	.032	1.31
	31	3.40	1.03		
	33	4.00	.82	.046	1.35
	35	4.20	.68		
	37	4.45	.68	.028	.73
	39	5.05	.70		
	41	5.30	1.12	.048	1.03
	43	No test.			
	45	No test.			
	48	7.40	1.16		

1417

FROM 8 A. M. 6-6 TO 8 A. M. 6-7. BESSEMER, JUNE 7, 1893.

5350	8.15 A. M.	1.07	.036	1.10
52	8.42	.89		
54	9.10	.93	.036	.73
56	10.07	.84		
58	10.25	1.21	.040	.80
60	11.00	.93		
62	11.25	.84	.042	.78

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
64	11.55	.93		
66	12.10 P. M.	1.02	.036	.83
67	12.55	1.07		
69	1.25		.042	.81
71	1.50	.56		
73	No test taken.			
75	2.35	.93	.031	.80
77	3.00	1.16		
79	3.20	.79	.031	.90
81	3.45	.77		
84	4.20	.61	.038	.95
86	4.50	.63		
88	5.10	.70	.031	.87
90	No test.			
93	6.35	1.03		
95	7.00	1.03	.042	.79
96	7.35	1.12		
98	8.05	1.05	.036	.85
5400	8.30	.93		
1	8.50	.89		
5403	9.05 P. M.	.89	.028	.85
6	9.50	1.03		
8	10.05	1.10	.028	.89
10	10.25	.93		
12	10.40	.89	.028	.99
13	11.20	1.17		
15	11.40	1.14	.038	1.14
18	12.25 A. M.	1.21		
20	12.55	.93	.034	.95
22	1.10	1.10		
24	1.30	.96	.026	.88
26	1.55	.96		
28	2.30	.86	.024	.80
30	2.45	.86		
32	3.45	1.03	.017	.91
34	4.15	.91		
36	4.30	1.14	0.15	.99
1118				
38	4.45	1.28		
40	5.05	1.33	0.21	1.01
42	5.25	1.45		
44	No test.			
46	No test.			
48	6.55	1.12	.028	.95

FROM 8 A. M. 6-7 to 8 A. M. 6-8. BESSEMER, JUNE 8, 1893.

5450	8.10 A. M.	1.07		
52	8.45	1.31	.026	1.11
54	9.10	1.07		
56	9.40	1.16	.017	1.01

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
58	10.05	1.49		
60	10.35	1.40	.028	1.89
62	No test.			
65	11.20	1.16		
66	12.10 P. M.	1.26	.038	.88
68	12.35	1.07		
70	1.00	.96	.029	.94
72	1.20	1.19		
74	1.40	1.03	.036	.94
76	1.50	1.00		
78	2.10	1.17	.025	1.05
80	2.50	1.24		
81	3.15	1.19	.038	1.13
83	3.35	1.17		
86	3.50	1.26	.042	1.03
88	4.20	1.28		
91	5.05	1.03	.042	.93
92	5.13	1.12		
94	6.10	1.14	.038	.82
96	6.30	1.14		
98	7.05	1.05	.038	.84
5500	7.55	1.03		
5502	8.20	.96	.036	1.23
5504	8.40	.93		
6	9.00	1.14	.040	.80
8	9.20	1.10		
10	9.40	1.26	.031	1.04
11	10.10	1.35		
14	10.40	1.35	.029	1.12
19	11.00	1.21		
18	11.40	1.52	.023	1.06
20	11.55	1.03		
21	12.50 A. M.	.93	.029	.98
24	1.05	.98		
1419				
26	1.25	.89	.029	.88
28	2.10	1.17		
30	2.30	1.07	.027	1.04
32	2.50	1.10		
34	3.30	1.31	.021	1.18
36	3.55	1.24		
38	4.30	1.07	.019	.98
40	5.10	1.73		
42	5.25	1.73	.019	1.29
44	No shot taken.			
46	No shot taken.			
48	7.13	1.26		
50	7.38	1.16	.026	.99
51	7.55	1.02		

FROM 8 A. M. 6-8 to 8 A. M. 6-9. BESSEMER, JUNE 9, 1893.

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
5554	8.45 A. M.	1.12	.023	.99
56	9.27	1.40		
59	10.00	1.12	.032	.95
60	10.35	.93		
63	11.30	1.26	.034	.97
65	11.50	1.07		
67	12.35 P. M.	1.02	.034	1.01
69	1.05	1.21		
71	1.20	.84	.040	.86
73	1.35	1.02		
75	1.50	.84	.021	1.00
77	2.40	.93		
79	2.15	1.02	.040	1.00
81	3.05	1.33		
83	3.35	1.56	.027	1.17
85	4.10	1.54		
88	5.00	1.42	.021	.94
90	5.20	1.35		
92	6.20	1.17	.031	.89
94	6.40	1.10		
95	7.10	1.26	.034	1.22
97	7.40	1.14		
99	8.00	1.14	.029	1.00
5602	8.20	1.24		
4	8.45	1.21	.036	.89
6	9.25	1.19		
8	9.50	1.40	.025	1.00
9	10.30	1.42		
11	11.00	1.12	.025	.96
13	11.40	1.07		
16	12.10 A. M.	1.14	.027	.93
1420				
18	1.20	1.10		
20	1.35	1.19	.031	1.04
22	1.55	.89		
24	2.20	.86	.034	.99
26	2.40	1.05		
28	3.00	.82	.624	.93
30	5.35	.91		
38	6.40	.91	.038	.79
40	7.10	.96		
41	7.45	.96	.032	.77

FROM 8 A. M. 6-9 to 8 A. M. 6-10. BESSEMER, JUNE 10, 1893.

5643	8.10 A. M.	1.14		
45	8.40	1.17	.032	.88
47	9.10	1.35		
49	9.35	1.14	.034	.76
51	10.05	1.31		

	Blow No.	Time.	Silicon.	Sulphur.	Manganese.
	53	10.20	1.19	.022	.90
	55	11.00	1.21		
	57	11.30	1.14	.042	.99
	59	11.50	1.17		
	61	12.20 P. M.	1.17	.040	.91
	62	12.40	1.19		
	64	1.05	1.28	.040	.87
	66	1.30	1.54		
	68	2.00	1.49	.028	.96
	70	2.25	1.28		
	71	2.37	1.31	.032	.95
	73	No test.			
	75	3.10	1.38		
	77	3.30	1.07	.028	1.04
	78	4.00	1.12		
	79	4.20	.98	.030	1.02
	82	4.50	1.12		
	84	5.15	1.16	.041	.91
	87	6.10	1.02		
	89	6.40	1.26	.041	.92
	91	7.00	1.30		
	93	7.25	1.21	.036	.96
	5695	7.40	1.40		
	97	8.25	1.26	.036	.36
	5700	8.40	1.07		
	5701	9.00	1.02	.028	.96
	03	9.20	1.16		
	5	9.45	.96	.024	.84
	7	10.55	1.10		
1421					
	9	11.00	1.00	.024	.90
	10	No test.			
6–10	12	12.10 A. M.	.79		
	15	12.35	.93	.024	.88
	17	1.00	.86		
	19	2.15	.75	.040	.89
	21	No test.			
	24	3.30	.79		.78
	25	4.05	.79	.030	
	28	4.25	.91		
	30	4.50	.98	.022	.87
	32	5.05	1.03		
	33	5.20	1.05	.022	.82
	35	6.20	.93		
	36	6.35	1.05	.034	.92
	39	7.15	1.35		
	42	7.45	1.21	.040	.86

FROM 8 A. M. 6-10 to 8 A. M. 6-12. BESSEMER, JUNE 12, 1893.

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
5743	8.27 A. M.	.89		
45	8.55	1.02	.030	.79
47	9.20	1.07		
49	9.50	.98	.044	.82
51	10.15	.84		
53	10.40	.79	.048	.75
61	7.10	1.26		
62	7.40	1.21	.048	.68
65	8.25	.84		
66	7.55	1.12	.042	.65
67	8.50	.98		
70	No test.			
72	9.15	1.00	.043	.57
75	10.10	1.33		
77	10.40	1.28	.046	.78
78	11.05	1.00		
80	11.45	1.12	.048	
82	No test.			
84	12.15 A. M.	1.35		
86	12.40	1.35	.048	.81
88	1.15	1.12		
90	2.00	1.14	.042	.75
92	2.23	1.00		
94	2.40	.98	.044	.89
96	4.10	1.05		
98	4.30	1.12	.034	.92
5800	5.00 A. M.	1.19		
1422				
2	6.30	1.26	.036	.89
4	7.10	.98		
6	7.40	1.12	.034	.87

FROM 8 A. M. 6-12 TO 8 A. M. 6-13. BESSEMER, JUNE 13, 1893.

5808	8.20 A. M.	1.07		
10	9.05	1.17	.036	.86
12	9.20	1.07		
14	9.55	.79	.036	.77
16	11.30	.75		
20	11.45	1.03	.030	.80
19	12.20 P. M.	.89		
21	1.00	1.03	.032	.89
24	1.30	.77		
25	1.50	.75	.020	.81
28	No test.			
30	2.50	.93		
32	3.20	1.19	.026	.87
34	3.45	1.12		
36	4.20	1.02	.028	.86
38	4.40	1.16		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
40	5.15	.98	.024	.89
44	6.00	1.12		
46	6.22	1.07	.028	.83
48	6.55	1.12		
50	7.21	.89	.044	.81
52	7.45	.93		
54	8.15	.98	.032	.78
57	8.40	1.12		
58	9.10	1.26	.026	.94
60	9.30	1.30		
62	10.15	.79	.032	.95
5863	10.44 P. M.	.91		
66	11.07	1.21	.040	.93
68	11.30	1.31		
71	12.00 M.	1.10	.042	.99
72	12.35 A. M.	1.17		
75	1.20	1.05	.046	.92
77	1.45	1.10		
79	2.00	1.10	.034	.89
81	2.25	.91		
83	No test.			
86	4.25	.79	.042	.80
88	4.45	.91		
91	6.40	.72	.036	.71
92	7.05	.84		
95	7.45	.77	.036	.83
1423				

FROM 8 A. M. 6-13 TO 8 A. M. 6-14. BESSEMER, JUNE 14, 1893.

6-13	5897	8.25 A. M.	.75	
	5900	9.50	.68	.036 .75
	1	10.20	.72	
	3	10.55	.68	.042 .71
	5	11.20	.72	
	7	11.45	.63	.044 .73
	9	12.05 P. M.	.84	
	11	12.35	.63	.042 .76
	13	12.50	.79	
	14	1.10	.93	.036 .81
	16	1.35	.93	
	20	2.20	.86	.040 .97
	21	3.00	.89	
	23	3.25	.79	.036 .84
	25	3.50	.70	
	27	4.00	.93	.036 .76
	29	4.25	.89	
	31	4.55	.98	.048 .68
	34	6.05	.84	
	36	6.25	.61	.036 .70
	38	7.45	.75	

	Blow No.	Time.	Silicon.	Sulphur.	Manganese.
	40	9.20	.75	.044	.72
	42	10.07	.81		
	44	10.45	.91	.034	.96
	46	11.05	1.21		
	48	11.30	1.24	.032	.88
	50	11.55	1.10		
6-14	5952	12.25 A. M.	1.05	.044	.74
	54	12.45	.93		
	56	1.22	1.00	.036	.72
	58	2.05	.75		
	60	2.30	.81	.036	.73
	62	2.45	1.12		
	64	3.10	1.24	.042	.82
	66	3.40	.98	Reanalyze	
	68	4.10	1.59	.034	.85
	70	4.45	1.63		
	72	5.00	1.75	.028	.79
	74	No test.			
	76	6.25	1.31		
	78	6.55	1.03	.036	.77
	81	8.00	1.07		

1424

FROM 8 A. M. 6-14 TO 8 A. M. 6-15. BESSEMER, JUNE 15, 1893.

	5983	No test.			
	84	8.30 A. M.	1.07	.030	.81
	86	9.10	.93		
	87	9.30	.84	.024	.79
	90	9.50	.89		
	93	10.10	1.02	.040	.82
	95	10.45	1.02		
	97	11.10	1.12	.048	.80
	98	11.45	1.20		
	6000	12.05 P. M.	1.12	.036	.81
	4	12.25	1.16		
	3	1.15	.21	.044	.70
	7	7.45	1.07		
	8	2.00	1.26	.032	.83
	10	2.55	1.07		
	11	3.20	.79	.028	.84
	14	3.40	.98		
	16	3.55	.98	.040	.76
	18	4.10	.93		
	20	4.45	.89	.038	.82
	22	5.05	1.07		
	24	5.20	.84	.040	.72
	27	6.00	1.12		
	29	6.50	1.16	.036	.86
	31	7.20	1.45		
	33	7.35	1.26	.036	.74

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
35	7.55	1.07		
37	8.25	.79		
39	9.20	.75	.056	.58
41	9.30	1.16		
43	10.00	1.16	.054	.82
45	No test.			
47	11.05	.89		
49	11.20	.93	.042	
51	11.40	1.00		.80
53	12.00 M.	.91	.042	.78
55	12.25 A. M.	.93		
57	12.45	.84	.044	.80
59	1.20	.86		
61	1.50	.75	.56	.82
62	2.10	.84		
65	3.00	.79	.050	.106
68	3.24	.71		
70	3.45	.86	.048	.85
1425				
72	4.10	1.03		
74	4.44	1.17	.046	.45
76	5.00	1.14		.15
79	6.10	1.03	.044	
81	6.35	1.00		
84	7.05	.98	.032	1.09
86	7.37	1.00		

FROM 8 A. M. 6-15 TO 8 A. M. 6-16. BESSEMER, JUNE 16, 1893.

6087	8.05 A. M.	.96	.036	.86
89	8.30	1.03		
91	8.55	.79	.032	.87
93	9.25	.93		
95	9.45	.93	.032	.85
98	No test.			
6100	10.25	1.12		
1	10.40	1.05	.040	.89
3	11.10	.98		
5	11.50	1.14	.028	.90
7	12.15 P. M.	1.14		
8	12.40	1.10	.056	.82
11	1.20	1.10		
13	1.45	1.00	.052	.99
15	2.10	.79		
17	2.35	.96	.060	.70
19	2.55	1.17		
21	3.10	.82	.052	.82
23	3.30	.84		
25	3.45	.84	.060	.89
26	4.05	.75		
29	4.35	.79	.044	.85

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
31	5.10	1.12		
33	No test.			
35	No test.			
37	6.10	1.21	.040	.86
39	7.10	1.26		
6141	7.35	1.31	.034	1.00
43	8.10	1.21		
46	8.25	1.12	.046	.98
48	8.45	.99		
50	9.15	.99	.044	.93
51	9.50	1.03		
53	10.20	.99	.036	.81
55	10.35	1.21		
57	10.55	1.19	.038	.94
59	11.20	1.24		
6-18 62	12.05	1.21	.044	1.01
1426				
65	12.50	.96		
67	1.30	.98	.042	.86
69	1.50	.98		
72	2.25	1.00	.038	.98
74	2.50	.96		
76	3.15	1.05	.030	.94
78	3.40	.98		
80	4.00	1.00	.046	.98
82	4.40	1.07		
84	4.55	.81	.044	.89
86	No test.			
80	No test.			
90	6.30	.77		
92	7.05	.53	.050	.81
94	7.25	.40		

FROM 8 A. M. 6-16 TO 8 A. M. 6-17. BESSEMER, JUNE 17, 1893.

6196	8.00 A. M.	.75	.049	.86
98	8.25	.72		
6200	8.40	.77	.042	.77
2	9.10	.75		
5	9.50	.98	.046	.79
7	10.15	.82		
9	10.40	1.07	.046	.83
10	11.15	.89		
14	11.45	.98	.040	.80
13	12.00 M.	.70		
15	12.30 P. M.	1.07	.052	.85
18	1.05	.68		
20	1.20	.86	.036	.81
22	1.35	.77		
24	2.00	.77	.046	.80

	Blow No.	Time.	Silicon.	Sulphur.	Manganese.
	26	2.25	.93		
	28	2.45	.91	.038	.89
	30	3.05	1.17		
	32	3.50	1.03	.042	.86
	34	4.10	1.12		
	36	4.45	1.02	.038	.91
	38	5.10	1.16		
	40	No test.			
	42	6.15	.26	.036	.94
	44	6.30	.93		
	46	7.15	1.21	.036	.93
	48	7.44	1.12		
	6250	8.00	.98	.052	1.01
	52	8.50	1.07		
1427					
	54	9.30	1.16	.040	1.02
	56	9.40	1.33		
	60	10 35	1.45	.030	1.07
	62	11.55	1.75		
6–17	64	12.10 A. M.	1.79	.030	1.14
	66	12.30	1.35		
	68	12.50	1.33	.026	1.08
	70	1.20	1.28		
	72	1.40	1.35	.030	.87
	74	2.00	1.40		
	76	2.40	1.31	.044	.93
	78	3.00	1.28		
	80	3.35	1.24	.032	.93
	82	3.50	1.14		
	84	4.15	1.19	.036	1.17
	86	4.30	1.05		
	88	5.00	1.28	.024	.96
	90	6.05	1.42		
	92	6.30	1.28	.028	.97
	94	7.10	1.17		
	96	7.30	1.17	.032	1.28

FROM 8 A. M. 6-17 TO 8 A. M. 6-19. BESSEMER, JUNE 19, 1893.

6–17	6298	8.00 A. M.	1.12		
	6300	8.25	1.26	.040	1.10
	2	9.15	1.10		
	Direct iron.				
6–18	6309	6.30 P. M.	1.19		
	10	6.50	1.07	.030	.91
	13	7.20	1.17		
	15	7.40	1.21	.034	.81
	17	8.05	1.46		
	19	8.25	1.38	.028	.92
	23	9.25	1.07		
	25	10.05	1.02	.022	.97

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
27	10.30	1.30		
29	10.45	1.07	.032	.89
31	11.05	1.45		
33	11.25	1.45	.044	.92
6-19 35	12.15 A. M.	1.02		
37	12.40	1.16	.028	.88
39	1.15	1.16		
41	1.30	1.21	.026	
44	2.10	1.12		
45	2.30	1.21	.026	.96
1428				
47	3.00	1.02		
49	3.15	1.49	.024	1.06
51	3.45	1.30		
53	No test taken.			
55	4.40	1.12	.024	.95
57	5.00	1.30		
59	5.20	1.35	.028	.98
61	No test taken.			
63	No test taken.			
65	7.15	1.24		
67	7.45	1.28	.028	

FROM 8 A. M. 6-19 TO 8 A. M. 6-20. BESSEMER, JUNE 20, 1893.

6370	8.15 A. M.	1.42		
71	8.30	1.45	.024	1.00
75	9.30	1.21		
76	9.53	1.05	.034	1.02
78	10.15	.93		
81	10.50	.81	.032	.99
84	11.15	1.03		
85	11.50	1.00	.036	.83
87	No test taken.			
89	12.25	1.54		
91	12.55	1.38	.208	.84
93	1.35	1.21		
94	2.00	1.14	.030	.92
99	2.45	1.35		
6401	3.15	1.28	.032	.88
3	3.35	1.14		
5	4.10	1.28	.022	.90
7	4.35	1.26		
9	5.00	1.21	.028	.94
11	5.15	1.38		
13	6.35	1.35	.038	.98
15	7.05	1.35		
17	7.25	1.42	.032	1.09
18	7.50	1.12		
21	8.15	1.17	.020	.99
23	9.10	1.19		

	Blow No.	Time.	Silicon.	Sulphur.	Manganese.
	25	9.40	1.17	.026	.96
	6427	9.55 P. M.	1.03		
	29	10.20	1.07	.024	.82
	32	10.35	1.16		
	33	10.55	1.12	.028	.79
	35	11.15	1.16		
	37	11.30	1.45	.028	.72
1429					
6–20	39	12.05 A. M.	1.45		
	41	12.35	1.24	.040	.85
	43	12.55	1.16		
	45	7.20	1.26	.036	.89
	47	1.40	1.30		
	49	2.00	.93	.028	.71
	51	2.15	1.21		
	53	2.30	.98	.028	.96
	55	3.05	1.02		
	57	3.35	1.12	.020	1.10
	59	3.45	1.07		
	62	4.00	1.26	.030	1.02
	63	4.20	1.12		
	65	4.35	.79	.050	.80
	67	5.05	1.16		
	69	No test taken.			
	71	No test taken.			
	73	No test taken.			
	75	7.00	.98	.040	1.12
	77	....	1.03		
	79	7.55	.98	.040	.90

FROM 8 A. M. 6-20 TO 8 A. M. 6-21. BESSEMER, JUNE 21, 1893.

6481	9.20 A. M.	1.07		
83	9.45	.79	.028	.88
85	10.10	.93		
87	No test taken.			
89	10.55	1.03	.042	.87
91	11.20	.84		
93	12.00 M.	.91	.040	.81
95	12.15 P. M.	.79		
96	12.35	.89	.040	.85
98	No test taken.			
6500	1.30	.79		
2	1.55	.77	.034	.86
4	2.15	.72		
6	2.45	.63	.038	.86
8	3.00	.72		
11	3.35	.75	.044	.84
14	3.55	.86		
16	4.30	.82	.046	.90

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
18	5.10	.77		
22	6.40	.75	.036	.97
24	7.00	.86		
26	7.35	.82	.036	.96
28	7.50	.68		
1430				
30	8.10	.68	.032	.98
32	9.00	.65		
34	9.20	.82	.038	.85
6537	10.10	1.03		
40	10.35	1.05	.032	.92
42	11.00	1.07		
44	11.20	1.02	.030	.87
45	11.50	.65		
47	12.15 A. M.	1.02	.022	.96
49	12.40	.79		
52	1.15	.93	.020	1.01
56	2.20	.65		
58	2.30	.61	.030	.82
60	2.50	1.16		
62	3.10	1.17	.020	.90
64	3.30	1.02		
66	4.00	.75	.044	.87
68	4.20	.79		
70	5.00	.93	.028	.81
76	6.30	.86		

FROM 8 A. M. 6-22 TO 8 A. M. 6-23. BESSEMER, JUNE 23, 1896.

6685	8.20 A. M.	.93	.022	.86
87	8.50	1.03		
91	9.35	1.17	.024	.93
93	9.55	1.17		
95	10.15	1.03	.048	.83
97	10.50	.89		
99	11.15	.84	.036	.89
6701	11.40	.93		
3	12.10 P. M.	.77	.036	.87
5	12.35	.89		
7	1.05	.77	.036	.95
9	1.23	.72		
11	1.50	.72	.030	.92
15	2.45	1.10		
17	3.10	1.05	.024	.87
18	3.50	1.07		
20	4.10	.75	.030	.90
22	4.35	.86		
24	4.50	.84	.036	.88
26	No test taken.			
28	6.20	1.05		
30	6.35	.81	.032	.98

	Blow No.	Time.	Silicon.	Sulphur.	Manganese.
	32	6.55	.96		
	34	7.15	.81	.038	1.03
1431					
	36	7.15	.77		
	38	8.10	.86	.026	.90
	40	9.05	.86		
	6742	9.30	.81	.046	.84
	45	10.00	.77		
	46	10.20	.79	.061	.76
	48	10.55	.70	....	.87
	52	11.35	.79	.057	
6–23	54	12.05 A. M.	.89	....	.96
	56	12.40	.84	.049	
	58	1.00	.93	....	.74
	60	1.30	1.21	.040	.88
	61	1.50	1.02		
	64	2.15	1.35	.034	.98
	66	2.35	1.16		
	68	3.00	1.35	.028	.97
	70	3.20	1.21		
	72	4.05	1.12	.030	.93
	74	4.30	.98		
	76	4.50	.89	.054	.91
	78	5.15	1.30		
	80	No test taken.			
	83	6.20	1.12	.026	.86
	85	No test taken.			
	88	7.30	1.14		
FROM 8 A. M. 6-23 TO 8 A. M. 6-24.				BESSEMER, JUNE 24, 1896.	
	6790	8.55 A. M.	1.38	.024	.97
	92	9.20	1.40	....	.87
	94	9.40	1.49	.026	
	96	10.20	1.40		
	98	10.45	1.47	.030	1.01
	6800	11.15	1.47		
	2	11.45	1.33	.040	.94
	4	12.15 P. M.	1.12		
	6	12.45	1.17	.034	.91
	8	1.10	1.21		
	10	1.20	1.10	.036	.94
	13	1.45	1.14		
	15	2.10	1.21	.020	.98
	17	2.25	1.35		
	18	2.45	1.07	.030	.93
	20	3.10	1.07		
	22	No test taken.			
	24	3.55	1.12	.027	.94
	26	4.15	1.51		
	28	4.25	1.26	.020	.91

ow No.	Time.	Silicon.	Sulphur.	Manganese.
30	5.00	1.24		
32	5.20	.98	.033	1.27
11	7.35	1.03		
13	8.20	1.14	.042	1.15
15	8.45	1.17		
17	9.20	1.17	.029	1.00
19	No test taken.			
6851	9.50	.86		
52	10.30	1.25	.029	.84
53	11.00	.93		
54	11.30	1.12	.018	1.03
55	11.50	1.16		
59	12.05 A. M.	1.21	.027	1.05
61	12.35	1.45		
63	1.10	1.21	.027	1.02
65	12.55	1.30		
66	1.35	1.12	.024	1.02
69	2.00	1.02		
71	2.20	.75	.034	.91
73	3.00	1.26		
75	3.15	1.16	.022	.95
77	3.50	1.02		
79	4.00	1.16	.048	.81
81	4.20	.98		
84	4.30	1.12	.040	.86
85	4.55	1.07		
86	5.15	1.40	.034	.83
88	6.55	1.46		
96	7.20	1.68	.017	.99

OM 8 A. M. 6-24 TO 8 A. M. 6-26. BESSEMER, JUNE 24, 1893.

6899	8.00 A. M.	1.54		
6901	8.40	1.31	.036	1.08
3	9.15	1.31		
5	9.40	1.40	.022	.88
7	10.05	1.21		
9	10.35	1.31	.036	.99
10	11.15	1.17		
12	11.35	1.35	.029	.94
15	12.10	1.59		
	Direct iron.			
5 6924	6.30 P. M.	.84		
27	7.00	.98	.036	
29	7.27	1.21	....	.94
31	8.00	1.40	.024	
33	8.35	1.31	....	.91
3				
37	9.20	1.42	.028	
39	10.05	1.00		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
41	10.35	1.33	.040	1.04
43	10.45	1.56		
45	11.05	1.70	.032	1.05
47	11.35	1.28		
49	12.15 A. M.	1.03	.028	.95
51	12.40	.86		
53	12.55	1.26	.026	.98
60	3.50	1.07		
63	4.20	1.21	.022	.87
65	4.35	1.26		
67	5.20	.98	.020	.89
71	7.10	1.07		
73	7.30	1.12	.028	.82
FROM 8 A. M. 6-26 TO 8 A. M. 6-27.			BESSEMER, JUNE 27, 1893.	
6975	8.20 A. M.	1.02		
77	8.35	1.02	.028	.81
79	9.10	1.07		
81	9.40	1.07	.028	.90
83	10.10	1.12		
85	10.30	1.16	.032	.92
88	11.00	1.21		
89	11.10	1.16	.022	.90
93	11.40	1.02		
95	12.05 P. M.	.98	.032	.90
97	12.30	.65		
99	12.55	.89	.024	.93
7002	1.15	.70		
4	1.45	.98	.016	.83
5	2.15	1.12		
7	2.30	1.07	.020	.97
9	3.00	.93		
11	3.20	.98	.030	.81
13	3.45	.98		
15	4.20	.75	.028	.76
17	5.05	1.03		
19	5.25	.93	.024	.78
26	6 30	.93		
28	7.05	.93	.024	91
30	7.35	1.03		
33	7.50	.93	.024	.94
34	8.20	.74		
7036	8.35	.60	.052	.79
39	9.25	.56		
1434				
41	10.00	.65	.052	.97
43	10.15	1.03		
46	10.45	.77	.036	.98
48	11.20	.77		
52	11.50	.63	.036	.97

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
54	12.10 A. M.	.70		
56	12.30	.79	.046	
58	12.50	.56		
60	1.15	.79	.048	.96
62	1.45	.75		
64	2.10	.77	.048	.89
66	2.30	.77		
68	3.10	1.12	.053	1.14
70	3.35	.93		
78	4.55	.70	.030	.82
81	5.50	.56		
86	7.10	.70	.044	1.00
FROM 8 A. M. 6-27 TO 8 A. M. 6-28.			BESSEMER, JUNE 28, 1893.	
7088	8.05	.79		
91	8.25	.65	.050	.83
92	8.45	.75	.038	
94	9.05	.79	....	.81
97	9.45	.84		
98	10.00	.84	.040	.83
7100	10.25	.79		
2	10.40	.56	.038	.75
3	11.00	.79		
6	11.30	.70	.030	.74
8	12.00	.84		
10	12.25 P. M.	.93	.033	.83
12	12.35	.89		
13	1.05	.84	.875	.73
16	1.35	.79		
18	1.50	.93	.043	.73
20	2.10	.89		
22	2.45	1.12	.030	.80
24	2.50	.79		
26	3.25	.61	.050	.81
28	3.50	.75		
30	4.10	.93	.040	.87
32	4.35	.61		
34	5.10	.84	.050	.71
36	No test.			
38	6.00	.61		
41	6.15	.89	.050	.66
1435				
7143	6.45	.75	.055	.91
45	7.20	.75		
46	7.50	.65		
48	8.20	.79	.020	.88
50	9.20	.89		
52	9.30	.93	.037	.98
54	10.00	.84		
55	10.20	.89	.050	.84

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
58	10.30	.98		
59	10.55	.89	.058	.96
61	11.15	.65		
64	11.35	.65	.065	.84
66	12.10	.54		
68	12.40	.61	.060	1.09
70	1.30	.51		
72	1.55	.82	.044	.90
74	2.10	.89		
76	2.55	.89	.033	.88
78	3.15	.93		
80	3.40	.93	.023	.83
82	4.00	.93		
84	4.20	1.17	.025	.87
86	4.30	1.40		
88	5.00	1.31	.023	.95
90	5.40	1.02		

FROM 8 A. M. 6-28 TO 8 A. M. 6-29. BESSEMER, JUNE 29, 1893.

7202	8.25 A. M.	1.16	.025	.90
5	9.20	1.02		
7	9.45	1.21	.030	.88
9	10.05	1.16	.035	.87
11	10.30	1.21	.035	.87
13	10.55	1.35		
15	11.25	1.26	.040	.85
17	11.40	1.49		
19	12.15 P. M.	1.26	.038	.89
21	12.30	1.12		
23	1.05	.98	.038	.88
25	1.20	.75		
27	1.35	1.02	.030	.87
29	1.55	1.21		
32	2.20	1.02	.030	.92
34	2.55	1.21		
35	3.35	.93	.025	.82
37	4.05	.75		
39	4.30	.89	.020	.87
1436				
41	4.40	1.17		
43	5.25	1.31	.033	.96
45	6.30	1.17		
46	7.10	1.17	.025	.87
48	7.50	.93		
50	8.00	1.07	.027	.81
53	8.35	.98		
56	8.55	1.12	.027	1.00
57	9.25	1.03		
60	9.40	1.31	.018	1.01
62	10.20	1.00		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
64	10.30	.75	.036	.99
66	11.00	1.10		
68	11.20	1.03	.030	1.00
70	11.50	1.10		
72	12.25 A. M.	1.10	.044	.97
74	1.00	1.17		
76	1.20	.98	.025	1.07
78	2.00	1.35		
80	2.25	.89	.027	1.05
82	2.45	.98		
84	8.25	1.14	.027	1.08
86	3.45	1.10		
88	4.10	1.05	.025	1.03
90	4.50	1.24		
92	5.20	1.14	.025	1.25
94	No test.			
96	No test.			
98	7.20	1.14		
7300	7.50	1.12	0.35	.95

FROM 8 A. M. 6-30 TO 8 A. M. 7-1. BESSEMER, JULY 1, 1893.

7410	8.15 A. M.	.70		
12	9.00	.65	.036	.80
13	9.25	.93		
16	10.10	.98	.036	.95
18	10.25	1.02		
20	11.00	.93	.034	.97
21	11.25	.98		
24	12.05 P. M.	.84	.056	.84
26	12.25	.89		
28	12.45	.98	.052	.81
30	1.00	1.02		
32	1.35	.58	.032	.73
34	1.50	.70		
36	2.00	.84	.038	.79
1437				
38	2.35	.93		
40	2.55	.98	.040	.87
42	3.15	.98		
44	3.35	.93	.036	.88
46	4.20	.93		
48	4.50	.65	.044	.84
51	5.10	.65		
55	6.10	.47	.038	.81
57	7.05	.65		
60	7.20	.70	.044	.92
62	7.45	1.03		
64	8.30	.75	.038	.85
65	8.50	.93		
7467	9.20	.75	.036	.91

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
71	9.45	1.49		
73	10.10	1.56	.040	.94
75	10.40	1.14		
78	11.35	.75	.040	.89
81	12.00 A. M.	.58		
83	12.20	1.03	.042	.88
85	12.45	1.03		
87	1.15	.96	.046	.80
89	1.40	.79		
91	2.10	.65	.038	.75
93	2.30	.62		
95	2.55	.58	.048	.73
97	3.40	.96		
99	4.00	.84	.028	.90
7501	4.30	.84		
05	4.50	.72	.046	.81
07	5.10	.61		

FROM 8 A. M. 6-29 TO 8 A. M. 6-30. BESSEMER, JUNE 30, 1893.

7308	8.10 A. M.	1.30		
4	8.45	1.21	.040	.99
6	9.15	1.07		
8	9.50	1.02	.032	.96
10	10.00	1.16		
12	10.20	1.30	.028	.93
14	10.40	1.12		
15	11.10	.93	.032	.82
18	11.50	1.02		
20	12.05 P. M.	.93	.032	.88
22	12.40	.98		
24	1.00	.93	.028	.88
25	1.20	.86		
27	1.40	.93		
1438				
31	2.20	.98	.032	.87
33	2.40	1.02		
34	3.10	1.12	.028	.88
36	3.45	1.03		
38	4.00	1.03	.022	.95
40	4.15	.93		
42	4.45	.93	.028	.95
44	6.10	1.16		
46	6.35	.65	.040	.86
48	6.50	.84		
50	7.30	.84	.042	.99
52	8.00	1.16		
54	8.25	.93	.032	.96
56	8.55	1.07		
58	9.05	1.12	.036	.83
60	9.30	.89		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
62	9.50	.93	.048	1.05
64	10.25	1.03		
66	10.45	1.12	.036	.93
69	11.25	.98		
71	11.55	.68	.028	.99
72	12.20	1.07		
74	12.35	.84	.040	.89
76	12.55	.84		
78	1.25	.61	.046	.84
80	1.40	.89		
82	2.10	.77	.046	.82
84	2.40	.96		
86	No test.			
88	3.05	.89	.040	1.00
90	3.40	.86		
92	No test.			
94	4.45	1.10	.036	.97
96	5.10	.93		
7404	7.10	.93	.040	.78
6	7.35	.89		
9	8.00 A. M.	.65	0.48	.82
FROM 6 A. M. 3-31 TO 6 A. M. 4-2.			BESSEMER, APRIL 2, 1894.	
6521	7.05 A. M.	1.33		
23	7.50	1.26	.026	.84
25	8.15	1.33		
27	8.45	1.45	.026	.82
29	9.15	1.49		
31	9.45	1.35	.026	.83
33	10.00	1.33		
1439				
35	10.35	1.26	.022	.90
38	11.10	1.49		
40	11.35	1.40	.024	.82
8	6.20 P. M.	.98		
10	6.55	.84	.038	.86
12	7.20	.82		
14	8.10	.65	.036	.84
16	8.40	.84		
20	9.15	1.03	.031	.85
22	9.40	1.07		
26	10.25	1.40	0.29	.83
28	10.35	1.35		
30	11.25	1.20	.031	.91
32	11.45	1.35		
34	12.20 A. M.	1.26	.036	.92
38	1.10	.96		
40	1.45	1.05	.034	.90
42	2.10	1.14		
44	2.30	1.10	.048	.93

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
46	3.05	1.03		
50	3.45	.91	.034	.86
52	4.15	1.10		
54	4.40	1.12	.024	.68
56	5.10	1.04		
58	5.25	1.21	.029	.75
60	5.40	1.31		

FROM 6 A. M. 4-2 TO 5 A. M. 4-3. BESSEMER, APRIL 3, 1894.

62	6.35 A. M.	1.05	.024	.85
64	7.00	1.05		
66	7.30	1.05	.024	.80
68	7.45	1.03		
71	8.00	1.07	.026	.77
73	8.25	1.07		
74	9.00	1.09	.019	.87
77	9.35	1.26		
78	9.50	1.23	.022	.81
80	10.30	1.21		
82	11.10	1.21	.024	.73
84	11.35	1.03		
86	12.00 M.	1.09	.024	.74
88	12.30 P. M.	.98		
92	1.10	1.03	.029	.79
94	1.30	.98		
96	1.55	1.03	.029	.90
98	2.35	1.21		
1440				
100	3.10	1.21	.029	.85
102	3.30	1.19		
104	4.00	1.19	.026	.87
106	4.20	1.21		
108	4.45	1.33	.022	.94
110	5.00	1.42		
112	5.30	1.45	.024	.93
115	6.00	1.24		
117	7.05	1.12	.029	.80
121	7.50 P. M.	1.31		
23	8.20	1.33	.026	.92
25	8.50	1.47		
27	9.20	1.42	.022	1.39
29	9.50	1.61		
31	10.20	1.52	.024	.90
33	10.50	1.47		
36	11.35	1.40	.019	.85
39	12.35 A. M.	1.35		
41	12.55	1.28	.022	.99
43	1.25	1.35		
45	1.50	1.33	.022	.89
47	2.15	1.40		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
49	2.40	1.28	.024	.88
51	3.03	1.10		
53	3.27	1.19	.022	.84
55	4.00	1.21		
57	4.35	1.07	.031	.88
59	4.45	1.00		
62	5.20	1.12	.036	.90
64	5.40	1.19		
FROM 6 A. M. 4-3 TO 6 A. M. 4-4.			BESSEMER, APRIL 4, 1894.	
167	6.25 A. M.	1.17	.031	.82
69	7.00	1.07		
71	7.40	1.03	.024	.87
73	8.05	1.03		
75	8.30	1.21	.026	.78
77	8.50	1.31		
79	9.20	.93	.031	.81
81	9.50	.93		
83	10.05	.89	.038	.74
85	10.35	.93		
87	11.00	1.17	.029	.76
89	11.30	1.26		
91	11.45	1.35	.026	.85
93	12.15 P. M.	1 35		
1441				
97	12.50	1.21	.019	.81
99	1.20	1.26		
201	1.45	1.23	.038	.77
3	2.10	1.03		
5	2.35	1.07	.041	.68
7	2.55	1.12		
9	3.20	1.00	.041	.73
11	3.35	1.03		
13	4.05	.93	.038	.79
15	4.45	1.24		
20	4.55	1.21	.031	.82
22	6.15	1.19		
24	6.50	1.12	.036	.73
226	7.20	.98		
28	7.55	1.21	.031	.89
31	8.45	1.19		
33	8.55	1.17	.043	.92
35	9.55	.96		
37	9.50	1.00	.041	.86
39	10.10	1.14		
41	10.35	1.26	.042	.88
43	11.05	1.31		
45	11.30	1.59	.053	.80
47	12.15 A. M.	1.19		
49	12.30	1.24	.031	.92

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
51	12.50	1.33		
53	1.10	1.31	.034	.86
55	1.35	1.28		
57	2.25	1.35	.031	.98
59	2.30	1.52		
61	2.55	1.38	.034	1.10
63	3.20	1.35		
65	4.05	1.05	.038	.75
67	4.22	1.07		
69	4.45	1.21	.034	.83
71	5.05	1.07		
73	5.20	1.19	.028	.84

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FROM 6 A. M. 4-4 TO 6 A. M. 4-5. BESSEMER, APRIL 5, 1894.

275	6.20 A. M.	1.12		
77	6.40	1.15	.034	.81
78	7.00	1.38		
81	7.20	1.17	.024	.86
83	8.00	1.33		
85	8.20	1.17	.024	.93
87	8.45	1.45		
89	9.05	1.38	.019	.87
91	9.50	1.35		
93	10.10	1.21	.017	.93
95	10.40	1.05		
97	11.05	1.03	.031	.84
99	11.50	.89		
301	1.15 P. M.	.70	.041	.76
3	1.40	.79		
5	2.00	.84	.039	.80
7	2.15	.93		
9	2.35	1.07	.041	.85
10	3.00	.93		
15	3.55	1.03	.043	.83
17	4.15	.81		
19	4.35	.79	.048	.82
23	5.05	.81		
27	6.15	.79	.036	.86
28	7.00	.63		
30	7.25	.91	.034	.75
32	7.45	.93		
34	8.15	1.19	.031	.90
36	8.45	.86		
39	9.29	1.12	.034	.95
41	9.55	1.26		
43	10.20	1.17	.031	.91
45	10.45	1.10		
47	11.45	1.07	.036	.81
49	12.25 A. M.	1.12		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
52	12.45	1.12	.031	.95
54	1.20	1.10		
56	1.35	1.14	.034	.88
58	1.55	1.00		
62	2.25	1.42	.036	.84
64	2.45	1.31		
66	3.00	1.24	.034	.87
69	3.25	1.24		
71	4.10	1.24	.029	.76
76	5.05	1.00		

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FROM 6 A. M. 4-5 TO 8 A. M. 4-6. BESSEMER, APRIL 6, 1894.

378	6.10 A. M.	1.24	.029	.92
80	6.45	1.12		
82	7.20	1.35	.024	1.01
84	7.45	1.33		
86	8.10	1.35	.022	.98
87	8.35	1.11		
90	9.10	1.31	.026	.95
91	9.30	1.26		
94	10.10	1.21	.022	.89
97	10.35	1.07		
99	10.55	.93	.036	.78
401	11.20	.98		
3	11.40	1.77	.022	.93
5	12.05 P. M.	1.33		
7	12.50	1.63	.022	.87
8	2.00	1.45		
11	2.30	1.49	.022	.97
13	2.50	1.45		
14	3.05	1.31	.024	.95
16	3.20	1.21		
18	3.45	1.33	.026	.77
21	4.10	1.38		
23	4.45	1.19	.024	.94
25	5.20	1.21		
27	6.15	1.21	.031	.79
29	6.55	1.28		
31	7.20	1.24	.031	.82
35	8.00	1.26		
37	8.30	1.19	.034	.86
39	8.55	1.24		
41	9.15	1.14	.034	.92
43	10.10	1.19		
47	10.45	1.17	.039	.70
49	11.15	.96		
51	11.35	1.17	.041	.65
53	11.50	1.14		
55	12.15 A. M.	.93	.046	.76

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
57	1.15	.98		
59	1.35	1.00	.039	.92
61	1.50	1.17		
65	3.05	1.19	.039	.80
67	3.25	1.26		
69	3.50	1.05	.029	.68
71	4.10	1.21		
73	4.50	.93	.040	.79

1444

FROM 6 A. M. 4-6 TO 6 A. M. 4-7. BESSEMER, APRIL 7, 1894.

475	6.25 A. M.	.79		
77	6.40	.84	.022	.84
79	7.05	1.17		
81	7.35	1.17	.033	.93
83	9.50	1.07		
87	10.55	1.03	.031	.75
86	12.15 P. M.	.79		
88	12.40	.75	.035	.73
91	1.00	.75		
93	1.30	.89	.037	.65
95	1.55	.98		
97	2.20	.98	.033	.75
99	2.40	1.03		
501	3.10	1.10	.026	.89
3	3.40	1.05		
5	4.10	.86	.040	.90
7	4.25	.93		
9	4.45	.89	.037	.87
11	5.05	.91		
13	6.10	1.35	.051	1.02
17	6.55	1.28		
19	7.25	1.26	.040	.81
21	7.55	1.31		
24	8.20	1.38	.031	.84
26	8.55	1.33		
29	9.15	1.49	.040	.83
31	10.10	1.33		
533	10.40 P. M.	1.24	.029	.85
35	11.00	1.07		
37	11.35	1.05	.040	.78
39	12.05 A. M.	1.10		
41	12.35	1.33	.035	.71
43	12.50	1.35		
46	1.55	1.14	.026	.77
50	2.50	1.47		
51	3.15	1.26	.031	.74
53	3.45	1.24		
57	4.30	1.10	.037	.76
59	4.45	1.07		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
62	5.15	1.12	.040	.82
64	5.40	1.10		

1445

FROM 6 A. M. 4-7 TO 6 A. M. 4-9. BESSEMER, APRIL 9, 1894.

565	6.15 A. M.	1.19	.042	.83
67	6.45	1.09		
69	7.15	1.17	.033	.80
71	7.50	1.35		
73	8.15	1.12	.024	.87
76	8.55	1.17		
77	9.15	1.21	.029	.87
79	9.45	1.31		
81	10.30	1.26	.020	.90
83	10.55	1.21		
85	11.25	1.08	.015	.85
87	12.55 P. M.	1.03		
89	1.15	.98	.028	.74
91	1.30	1.00		
93	2.10	1.12	.020	.79
95	2.40	1.31		
99	6.20	1.49		
604	7.10	1.61	.026	.87
6	7.30	1.68		
7	8.05	1.68	.026	.80
10	8.45	1.45		
13	9.10	1.38	.031	.76
15	9.30	1.52		
17	10.00	1.54	.026	.88
19	10.25	1.63		
21	10.45	1.56	.022	.98
23	11.10	1.61		
25	11.25	1.63	.029	.86
29	12.20 A. M.	1.47		
30	12.40	1.42	.040	.83
32	1.00	1.80		
35	3.20	1.82	.029	.91
37	4.10	1.98		
39	4.35	2.15	.022	.93
41	5.35	1.98		

FROM 6 A. M. 4-9 TO 6 A. M. 4-10. BESSEMER, APRIL 10, 1894.

643	6.15 A. M.	1.98	.026	.85
45	6.45	1.66		
47	7.15	1.63	.031	.86
49	7.45	1.61		
51	8.05	1.75	.026	.91
53	8.40	1.77		
55	9.00	1.75	.029	.85
57	10.10	1.77		

1446

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
59	10 45	1.80	.026	.92
61	11.10	1.82		
64	11.35	1.91	.024	.87
69	12.35 P. M.	1.87		
71	1.05	1.75	.031	.94
73	1.35	1.77		
75	1.50	1.87	.029	.92
77	2.10	1.87		
79	2.45	1.87	.029	.92
81	3.10	1.54		
83	3.30	1.73	.020	
85	3.45	2.01		
89	4.30	1.91	.016	.95
91	4.55	2.05		
94	5.40	1.79	.031	.85
96	6.30	1.49		
98	6.50	1.59	.018	.82
700	7.10	1.54		
2	7.30	1.73	.018	.90
4	7.50	1.71		
6	8.25	1.53	.022	.81
8	8.45	1.63		
10	9.00	1.35	.015	.89
12	9.35	1.35		
14	10.10	1.26	.029	.86
16	10.30	1.21		
19	11.10	1.21	.037	.82
20	11.20	1.26		
22	11.50	1.24	.026	.87
24	12.15 A. M.	1.31		
26	12.35	1.26	.031	.80
29	1.15	1.24		
31	1.35	1.33	.040	.79
32	1.55	1.33		
34	2.30	1.63	.036	.74
35	2.50	1 82		
38	3.15	1.77	.031	.82
39	3.40	1.47		
42	4.00	1.40	.031	.94
44	4.25	1.35		
46	4.40	1.31	.034	.82
48	5.00	1.28		
50	5.25	1.19	.037	.87
52	5.40	1.19		

1447

FROM 6 A. M. 4-10 TO 6 A. M. 4-11. BESSEMER, APRIL 11, 1894.

755	6.25 A. M.	1.28	.031	.78
57	7.25	1.47		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
59	7.45	1.38	.031	.86
61	8.10	1.33		
65	8.40	1.47	.031	.94
67	9.00	1.17		
69	9.40	1.31	.029	.96
71	10.00	1.26		
74	10.20	1.26	.029	.67
76	10.45	1.31		
78	11.00	1.28	.029	.81
80	11.25	1.40		
82	11.55	1.26	.031	.89
84	12.30 P. M.	1.24		
86	12.50	1.45	.035	.81
88	1.10	1.52		
90	1.35	1.40	.037	.77
92	2.05	1.40		
96	2.35	1.56	.033	.93
98	3.05	1.52		
801	3.45	1.73	.024	.83
3	4.10	1.68		
6	4.35	1.49	.031	.76
8	4.50	1.40		
10	5.05	1.05	.037	.82
13	6.35	1.28		
15	6.50	1.21	.031	.83
18	7.45	1.28		
21	8.10	1.45	.036	.85
22	8.30	1.49		
24	8.45	1.45	.037	.79
26	9.05	1.33		
28	9.25	1.35	.031	.82
30	9.45	1.35		
32	10.10	1.63	.037	.75
34	10.30	1.47		
36	10.50	1.40	.048	.84
38	11.15	1.68		
40	11.40	1.54	.029	.82
42	12.00	1.49		
44	12.30 A. M.	1.54	.040	.83
46	12.40	1.59		
48	1.00	1.49	.040	.72
50	1.25	1.59		
52	1.50	1.54	.033	.74
1448				
54	2.10	1.40		
56	2.25	1.63	.031	.80
58	2.45	1.40		
60	3.10	1.35	.046	.77
64	3.45	1.35		
66	4.05	1.49	.037	.90

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
68	4.30	1.49		
69	4.45	1.49	.026	.85
72	5.15	1.68		
74	5.40	1.91	.035	.79

FROM 6 A. M. 4-11 TO 6 A. M. 4-12. BESSEMER, APRIL 12, 1894.

876	6.10 A. M.	2.01		
78	7.00	1.75	.044	.88
80	7.45	1.31		
82	8.10	1.26	.037	.79
84	8.30	1.28		
86	8.40	1.42	.040	.74
88	9.18	1.40		
90	9.40	1.45	.040	.74
92	9.55	1.52		
94	10.10	1.14	.042	.60
96	10.35	1.26		
99	11.00	1.68	.048	.73
901	11.20	1.61		
3	11.50	1.14	.037	.77
5	12.05 P. M.	1.07		
8	12.30	.96	.033	.67
10	12.50	.93		
12	1.15	.93	.037	.77
14	1.35	.68		
16	1.55	1.33	.066	.73
18	2.15	1.33		
20	2.30	1.19	.033	.63
22	2.45	1.35		
24	3.00	1.26	.042	.67
26	3.15	1.35		
28	3.40	1.87	.029	.62
30	4.10	1.82		
32	4.35	1.87	.035	.79
34	4.55	1.59		
36	5.15	1.31	.029	.80
39	5.40	1.40		
41	6.20	1.03	.031	.74
43	6.45	1.82		
45	7.10	1.21	.033	.68
1449				
47	7.50	1.31		
49	8.05	1.45	.031	.70
51	8.25	1.54		
52	8.50	1.35	.029	.67
55	9.15	1.49		
57	9.55	1.45	.031	.70
59	10.20	1.54		
61	10.40	1.49	.037	.82
63	11.00	1.42		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
65	11.25	1.59	.036	.85
67	11.45	1.56		
68	12.05 A. M.	1.45	.046	.87
70	12.30	1.26		
72	12.45	1.10	.046	.76
75	1.15	1.03		
78	1.40	1.14	.044	.74
79	2.05	1.00		
81	2.35	1.07	.046	.78
83	3.00	1.14		
84	3.35	1.12	.043	.96
86	4.05	1.17		
89	4.25	1.19	.048	.82
91	4.50	1.19		

FROM 6 A. M. 4-12 TO 6 A. M. 4-13. BESSEMER, APRIL 13, 1894.

993	6.05 A. M.	1.35	.045	.75
95	6.20	1.24		
97	6.50	1.03	.022	.71
99	7.10	1.10		
1004	7.55	1.03	.042	.64
6	8.40	.98		
8	9.00	1.00	.044	.70
10	9.30	1.00		
12	9.40	.93	.055	.86
14	10.05	1.12		
16	10.20	1.35	.048	.67
18	10.55	1.21		
20	11.20	1.24	.051	.72
23	11.40	1.00		
25	12.00	1.19	.053	.80
27	12.20 P. M.	1.19		
29	12.35	1.17	.046	1.20
31	1.30	1.26		
34	2.05	1.17	.042	.90
36	2.40	1.12		
40	2.55	1.12	.055	.89
1450				
42	3.10	1.21		
45	3.30	1.12	.040	.98
47	3.55	1.21		
49	4.25	1.40	.035	.75
51	4.50	1.26		
54	5.15	1.49	.051	.78
56	5.30	1.49		
58	6.10	1.26	.046	.71
60	6.45	1.07		
61	7.05	1.21	.046	.83
63	7.30	1.12		
67	7.55	1.26	.042	.80

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
68	8.20	1.17		
70	8.40	1.07	.051	.76
72	9.00	1.07		
74	9.15	1.31	.042	.76
76	9.40	1.47		
78	10.00	1.47	.040	.78
80	10.20	1.63		
82	10.40	1.82	.033	.86
83	11.10	1.63		
88	11.55	1.49	.040	.74
90	12.10 A. M.	1.26		
92	12.25	1.31	.040	.72
93	12.45	1.24		
95	1.05	1.49	.040	.81
97	1.30	1.52		
98	1.45	1.38	.037	.77
1100	2.05	1.54		
1103	2.30	1.63	.035	.74
5	2.45	1.49		
7	3.00	1.52	.046	.73
9	3.30	1.47		
11	3.50	1.42	.053	.70
13	4.05	1.35		
15	4.25	1.24	.061	.87
17	4.45	1.26		
19	5.20	1.14	.055	.82
21	5.40	1.33		

1451

FROM 6 A. M. 4-13 TO 6 A. M. 4-14. BESSEMER. APRIL 14, 1683.

1123	6.20 A. M.	1.40	.040	1.00
25	7.20	1.24		
27	7.45	1.35	.044	.80
29	8.15	1.31		
31	8.40	1.40	.035	.94
36	9.35	1.54		
38	10.10	1.49	.044	.87
41	10.45	1.54		
43	11.05	1.54	.048	.86
45	11.25	1.21		
47	11.45	1.21	.048	.82
49	12.10 P. M.	1.26		
52	12.45	1.14	.044	.83
54	1.10	1.10		
56	1.40	1.05	.046	.95
58	2.00	1.19		
60	2.25	1.19	.048	.74
62	2.45	1.61		
64	3.05	1.35	.042	.80
66	3.54	1.49		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
68	4.10	1.27	.037	.78
70	4.31	1.17		
72	4.58	1.07	.040	.66
74	5.15	1.17		
76	6.05	1.21	.040	.84
78	6.35	1.35		
80	6.55	1.26	.029	.80
82	7.25	1.26		
84	7.40	1.07	.033	.72
85	8.10	1.21		
89	8.35	1.26	.037	.78
91	9.15	1.35		
93	9.25	1.26	.040	.80
94	9.50	1.31		
96	10.05	1.45	.057	.77
98	10.40	1.19		
1202	11.25	1.14	.048	.82
4	12.00	1.21		
6	12.20 A. M.	1.19	.040	.76
8	12.50	1.21		
10	1.20	1.17	.040	.76
12	1.55	1.33		
14	2.05	1.35	.042	.80
16	2.40	1.31		
1452				
18	3.00	1.35	.042	.74
20	3.20	1.26		
22	3.40	1.14	.038	.70
24	4.15	1.03		
26	4.45	.89	.040	.73
29	5.10	1.26		
31	5.35	1.14	.040	.72

FROM 6 A. M. 4-14 TO 6 A. M. 4-16. BESSEMER, APRIL 16, 1894.

1232	6.05 A. M.	1.26		
34	6.20	1.49	.038	.65
37	7.25	1.14		
39	7.53	1.14	.042	.81
41	8.20	1.28		
43	8.43	1.26	.035	.91
45	9.20	1.24		
47	9.46	1.21	.046	.80
49	10.15	1.03		
51	10.35	1.19	.044	.78
53	10.55	1.07		
55	11.15	1.12	.046	.79
57	11.30	1.10		
59	12.00	1.17	.044	.77
61	12.26 P. M.	1.10		
63	12.55	1.12	.057	.80

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
65	1.15	.91		
68	1.45	.79	.044	.76
73	6.32	1.77		
75	6.50	1.77	.024	.90
76	7.15	1.52		
78	7.30	1.52	.031	.79
80	7.45	1.54		
82	8.10	1.33	.024	.89
83	8.35	1.35		
85	9.20	1.51	.024	.71
88	9.40	1.31		
90	10.27	1.40	.024	.70
92	10.55	1.12		
95	11.10	1.07	.029	.87
96	11.40	1.20		
98	12.00	1.31	.024	.69
1300	12.35 A. M.	1.12		
2	1.00	1.21	.026	.67
4	1.45	1.35		
6	3.55	1.21	.035	.60
8	4.20	1.21		
10	6.20	.84	.035	.73
12	6.45	.89		

1453

FROM 6 A. M. 4-16 TO 6 A. M. 4-17. BESSEMER, APRIL 17, 1894.

1314	7.10 A. M.	.81	.041	.76
16	7.40	.98		
18	8.45	.86	.042	.65
20	9.10	.89		
22	10.15	1.19	.040	.65
24	11.10	1.03		
25	11.40	.98	.042	.69
29	12.30 P. M.	.79		
31	1.25	.98	.042	.70
33	1.55	1.21		
35	2.30	1.33	.046	.70
37	3.00	1.17		
39	3.30	1.07	.064	.78
41	4.00	1.07		
43	4.20	1.00	.044	1.28
45	4.40	.93		
47	5.20	1.03	.075	.65
51	6.05	1.14		
55	6.35	1.26	.051	.65
57	7.05	1.14		
59	7.30	1.38	.048	
61	8.25	1.42		
63	8.55	1.38	.053	.82
65	9.20	1.31		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
66	9.40	1.24	.051	
68	10.30	1.19		
71	10.55	.70	.070	.60
73	11.45	1.17		
77	12.30 A. M.	.98	.053	
79	1.00	1.21		
81	1.55	1.59	.046	.70
83	2.20	1.49		
85	3.10	1.31	.040	
89	4.10	1.35		
91	4.25	1.26	.033	.86
93	5.00	1.31		
95	5.10	1.07	.029	
97	5.35	1.21		

1451

FROM 6 A. M. 4-17 TO 6 A. M. 4-18. BESSEMER, APRIL 18, 1894.

1398	6.35 A. M.	1.19	.042	.69
1400	7.40	1.28		
1	8.00	.98	.046	
4	8.25	.86		
7	9.15	.89	.053	.60
11	9.35	.91		
9	9.50	.79	.043	
12	10.35	.72		
14	10.55	.81	.048	.60
16	11.25	.81		
18	11.45	.89	.044	
20	12.10 P. M.	.86		
22	1.10	.81	.048	.72
24	1.25	1.33		
25	1.50	1.10	.039	
27	2.15	1.28		
28	3.00	1.12	.042	.88
32	3.45	1.19		
34	4.10	1.24	.042	
36	4.45	1.47		
38	5.20	1.42	.037	.61
40	6.00	1.26		
41	6.25	1.21	.042	
44	7.25	1.52		
46	7.50	1.49	.046	.95
48	8.05	1.26		
50	8.40	1.21	.070	
1452	8.55 P. M.	1.31		
55	9.35	1.28	.037	.69
57	9.55	1.28		
59	10.35	1.35	.037	
61	11.30	1.12		
63	12.00	1.17	.044	.60

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
65	12.20 A. M.	1.21		
67	1.30	1.17	.040	
69	2.00	1.17		
71	2.30	1.35	.035	.74
73	3.00	1.21		
75	3.20	1.07	.042	
77	3.40	1.07		
79	4.05	1.21	.040	.60
81	4.45	1.31		
83	5.20	.98	.040	
85	5.40	.89		

1455

FROM 6 A. M. 4-18 TO 6 A. M. 4-19. BESSEMER, APRIL 19, 1894.

1487	6.15 A. M.	1.33	.033	.70
88	6.40	1.21		
91	7.30	1.42	.034	
93	8.00	1.40		
95	8.20	1.38	.044	.71
97	9.00	1.40		
99	9.25	1.38	.041	
1501	9.55	1.40		
3	10.25	1.17	.038	.76
5	10.55	1.19		
7	11.15	1.40	.052	
9	11.40	1.73		
11	12.15 P. M.	1.59	.044	.72
13	12.45	1.49		
15	1.10	1.52	.028	
17	1.35	1.91		
20	2.00	1.66	.048	.68
22	2.30	1.63		
24	3.00	1.28	.025	
26	3.30	1.14		
27	4.05	1.14	.030	.61
29	4.20	1.14		
31	4.35	.98	.028	
33	4.55	1.19		
34	5.20	1.35	.029	.67
36	6.00	1.59		
38	6.35	1.24	.037	
1540	7.00	1.26		
42	7.35	1.19	.035	.81
44	8.00	1.35		
47	8.35	1.33	.030	
49	9.05	1.35		
50	9.30	1.31	Lost.	.75
52	9.50	1.33		
56	10.25	1.17	.032	
58	11.35	1.17		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
62	12.20 A. M.	1.12	.030	.66
64	12.45	.98		
66	1.00	.93	.030	
68	1.55	.89		
70	2.25	1.07	.035	.80
74	3.00	1.12		
76	3.30	1.12	.032	
78	4.15	.98		
80	5.00	1.12	.032	.60
82	5.35	1.21		

1456

FROM 6 A. M. 4-19 TO 6 A. M. 4-20. BESSEMER, APRIL 20, 1894.

1584	6.25 A. M.	1.31	.039	
86	6.50	1.31		
87	7.40	1.35	.033	.84
89	8.30	1.12		
91	8.50	1.03	.038	
93	9.20	1.07		
95	9.55	1.05	.046	.75
96	10.20	1.10		
1600	10.45	1.07	.045	
1	11.05	1.03		
3	11.20	1.07	.045	.85
5	11.50	1.17		
7	12.25 P. M.	1.07	.049	
9	12.55	1.05		
11	1.20	.84	.060	.65
13	1.55	.77		
15	2.30	.75	.045	
17	2.50	.70		
19	3.20	.93	...	.65
21	3.45	.96	.055	
23	4.25	.91	.075	
25	4.55	1.17		
27	5.25	1.14	.067	.63
30	6.20	1.00		
32	7.45	.96	.062	
34	8.30	1.10		
36	9.20	1.17	.053	1.06
38	9.45	1.19		
40	10.15	1.31	.048	
42	10.35	1.31		
44	10.50	1.21	.044	.60
46	11.15	1.35		
48	11.50	1.31	.053	
50	12.30 A. M.	1.26		
52	12.55	1.31	.044	.61
54	1.32	1.35		
56	1.55	1.40	.044	

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
58	2.35	1.35		
60	3.05	1.59	.035	.60
62	3.45	1.49		
64	4.05	1.54	.035	
66	4.30	1.35		
68	4.55	1.35	.037	.53
70	5.30	1.12		
73	6.20	.98	.051	

1457

FROM 6 A. M. 4-20 TO 6 A. M. 4-21. BESSEMER, APRIL 21, 1894.

1675	7.05 A. M.	1.26		
77	7.40	1.17	.053	.65
79	8.10	1.33		
82	8.40	1.59	.046	
84	9.00	1.52		
85	9.40	1.31	.048	.56
87	10.10	1.24		
89	10.40	1.24	.049	
91	11.15	1.17		
93	11.35	1.24	.944	.62
95	11.50	1.21		
98	12.20 P. M.	1.33	.031	
1700	1.00	1.31		
1	1.30	1.28	.048	.64
3	2.00	1.47		
5	2.15	.96	.067	
7	2.30	1.00		
11	2.55	1.03	.046	.65
12	3.35	1.03		
14	3.55	1.03		
15	3.55	1.24	.044	
16	4.20	1.26		
18	4.50	1.26	.044	.68
20	6.15	1.17		
22	6.35	.89	.053	
24	6.55	1.26		
26	7.15	1.17	.035	.54
28	7.40	1.31		
30	8.25	1.31	.039	
34	8.55	1.07		
36	9.30	1.25	.035	
38	10.10	1.28		
42	10.45	1.26	.025	
44	11.30	.98		
46	11.50	.93	.041	.71
48	12.20 A. M.	.98		
50	12.30	.93	.039	
52	12.55	.98		
55	1.50	1.26	.032	.57

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
60	2.25	1.17		
62	2.50	1.03	.027	
64	3.30	1.17		
66	3.45	1.17	.021	.64
68	4.05	1.14		
70	4.30	1.17	.025	
1458				
72	4.50	1.35		
74	5.15	1.26	.035	.71
76	5.50	1.17		
FROM 6 A. M. 4-21 TO 6 A. M. 4-23.			BESSEMER, APRIL 23, 1894.	
1778	6.40 A. M.	1.17	.030	
82	7.50	1.42		
84	8.20	1.24	.032	.59
86	8.45	1.21		
88	9.15	1.26	.035	
90	9.45	1.26		
92	10.15	1.21	.039	.71
94	10.40	1.66		
95	11.00	1.68	.035	
97	11.25	1.82		
1800	12.05 P. M.	1.63	.053	.81
2	12.35	1.14		
5	12.50	1.12	.041	
6	1.30	1.03		
8	1.55	1.24	.025	.82
10	2.15	1.07		
15	6.30	1.61	.028	.60
17	7.10	1.66		
18	7.40	1.49	.028	.58
21	8.20	1.63		
23	8.55	1.38	.021	.79
24	9.25	1.00		
26	10.00	1.21	.030	.70
29	10.50	1.35		
31	11.05	1.33	.030	.71
33	11.30	1.07		
35	12.05 A. M.	1.14	.035	.72
37	12.30	1.24		
39	12.50	2.57	.035	.76
41	1.10	2.10		
43	1.40	2.05	.028	.75
45	2.00	1.91		
47	2.20	1.49	.035	.78
49	2.50	1.45		
52	3.15	1.38	.032	.74
53	3.50	1.35		
55	4.25	1.49	.037	.72
57	4.40	1.40		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
59	5.00	1.19	.028	.76
61	5.15	1.33		
63	5.40	1.31	.039	.75

1459

FROM 6 A. M. 4-23 TO 4 A. M. 4-24. BESSEMER, APRIL 24, 1894.

1865	6.10 A. M.	1.31		
67	6.25	1.40	.041	.70
69	7.15	1.26		
71	7.45	1.31	.041	.72
73	8.10	1.31		
75	8.30	1.49	.021	.67
77	9.00	1.49		
79	9.35	1.40	.030	.72
81	9.50	1.40		
83	10.15	1.45	.027	.78
86	10.45	1.82		
88	11.10	1.63	.027	.77
91	11.45	1.63		
93	12.05 P. M.	1.49	.030	.78
95	12.35	1.17		
97	1.00	1.31	.035	.84
99	1.22	1.03		
1901	1.50	1.03	.032	.74
4	2.15	1.21		
6	2.40	1.17	.035	.72
8	3.00	1.13		
10	3.15	1.21	.035	.69
12	3.55	1.49		
16	4.15	1.28	.032	.75
18	4.40	1.47		
20	5.00	1.40	.039	.85
22	5.22	1.47		
23	6.10 P. M.	1.45	.038	.79
25	6.30	1.33		
27	6.50	1.19	.039	.88
29	7.15	1.21		
31	7.50	1.21	.041	.89
33	8.10	1.26		
35	8.40	1.10	.045	.75
38	9.05	1.05		
39	9.20	1.00	.036	.82
41	9.35	.98		
43	10.00	1.06	.039	.85
45	10.20	1.03		
47	10.40	1.19	.039	.86
49	10.55	1.07		
51	11.20	1.00	.044	.72
53	11.40	.91		
55	12.05 A. M.	.91	.046	.83

	Blow No.	Time.	Silicon.	Sulphur.	Manganese.
	58	12.35	1.47		
1460					
	60	1.00	1.38	.039	.86
	61	1.20	1.38		
	63	1.50	1.38	.032	.70
	65	2.10	1.42		
	67	2.40	1.31	.041	.82
	69	3.00	1.21		
	71	3.20	1.05	.032	.84
	73	3.35	1.05		
	75	4.00	.93	.041	.91

FROM 4 A. M. 4-24 TO 6 A. M. 4-25. BESSEMER, APRIL 25, 1894.

1977	4.20 A. M.	.91		
79	4.40	1.21	.032	.82
82	5.35	1.63	.035	
84	6.05	1.40		
86	6.45	1.49	.032	.84
88	7.25	1.54		
90	8.05	1.54	.035	.67
92	8.25	1.49		
94	8.55	1.54	.025	.74
95	9.15	1.35		
97	9.45	1.35	.025	.75
99	10.05	1.31		
2002	10.35	1.21	.032	.75
4	11.05	1.40		
6	11.25	1.35	.035	.71
8	11.50	1.17		
10	12.10 P. M.	1.26	.037	.76
12	12.25	1.26		
14	12.45	1.31	.032	.72
16	1.00	1.26		
18	1.15	1.26	.032	.70
20	1.35	1.31		
22	2.10	1.17	.035	.68
24	2.35	1.26		
26	2.50	1.03	.037	.92
28	3.25	1.05		
31	3.45	.98	.035	.85
33	4.10	.98		
35	4.30	.96	.037	.78
37	4.40	1.12		
39	5.00	1.19	.038	.83
41	6.10	1.07		
43	6.40	1.12	.038	.78
45	7.05	1.10		
47	7.25	1.07	.034	.85
1461				
49	7.40	1.14		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
51	8.10	1.07	.030	.92
53	8.50	1.05		
55	9.15	1.12	.030	1.03
57	10.10	1.42		
59	10.25	1.47	.027	.88
61	10.40	1.19		
63	11.15	1.35	.026	.74
65	11.45	1.31		
67	12.00	1.33	.028	.80
69	12.15 A. M.	1.21		
71	12.50	1.21	.028	.73
72	1.05	1.33		
75	1.45	1.21	.024	.78
77	2.20	1.05		
80	2.40	1.05	.026	.71
82	3.00	1.19		
84	3.15	1.14	.024	.72
85	3.35	1.07		
88	3.55	1.05	.028	.92
89	4.10	1.07		
91	4.45	1.00	.032	.80
93	5.05	1.14		
95	5.25	1.05	.036	.72
97	5.40	1.05		

FROM 6 A. M. 4-25 TO 6 A. M. 4-26. BESSEMER, APRIL 26, 1894.

2101	6.25 A. M.	1.14	.032	.76
3	7.05	1.03		
5	7.30	.91	.028	.73
7	8.00	.98		
9	8.10	1.03	.034	.74
11	8.35	1.03		
13	8.50	.98	.026	.75
15	9.10	1.07		
16	9.20	1.12	.032	.95
18	9.45	1.40		
20	10.05	1.35	.024	.95
22	10.30	1.21		
24	11.05	1.35	.032	.80
26	11.45	1.31		
29	12.10 P. M.	1.12	.024	.75
31	12.30	1.21		
33	12.55	1.17	.020	.80
35	1.30	1.07		
37	1.50	1.12	.022	.90
39	2.10	1.07		
1462				
41	2.35	1.40	.020	1.07
43	3.15	1.35		
45	3.50	1.42	.022	.96

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
48	4.40	1.49		
50	5.00	1.31	.022	.76
52	5.15	1.40		
54	5.35	1.35	.022	.85
56	6.10	1.28		
58	6.45	1.24	.028	.84
60	7.05	1.66		
62	7.20	1.42	.022	.85
64	8.05	1.31		
66	8.25	1.28	.032	.94
68	8.40	1.33		
70	9.05	1.45	.024	.80
72	9.40	1.52		
76	10.05	1.61	.026	.65
77	10.20	1.91		
78	10.50	1.89	.020	.72
80	11.30	1.45		
82	11.45	1.19	.030	.80
84	12.00	1.10		
86	12.35 A. M.	1.45	.030	.95
89	12.50	1.28		
91	1.10	1.54	.033	.97
92	1.30	1.75		
94	1.50	1.66	.024	.90
96	2.05	1.68		
98	2.35	1.70	.026	.89
2200	3.05	1.59		
2	3.25	1.31	.032	.85
5	4.05	1.28		
9	4.55	1.00	.032	.76
11	5.20	1.07		
13	5.50	1.17	.034	.74

FROM 6 A. M. 4-26 TO 6 A. M. 4-27. BESSEMER, APRIL 27, 1894.

2215	6.20 A. M.	1.40		
17	6.40	1.49	.034	1.04
20	7.35	1.45		
23	8.00	1.35	.032	1.00
25	8.25	1.35		
27	8.45	1.49	.038	.87
29	9.15	1.21		
32	10.05	1.26	.034	.71
35	10.30	.89		
1463				
37	10.45	1.03	.038	.67
39	11.15	1.03		
41	11.45	1.40	.030	.72
43	12.10 P. M.	1.40		
45	12.55	1.07	.026	.91
47	1.05	1.17		

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
49	1.25	1.21	.032	.80
51	1.55	1.07		
53	2.40	1.24	.028	1.15
55	2.55	1.31		
59	3.35	1.19	.030	.72
61	4.05	1.12		
63	4.25	1.00	.033	.69
65	4.40	1.12		
67	4.55	1.10	.032	.76
69	5.15	1.21		
71	6.10	1.17	.032	.82
74	6.45	1.28		
2276	7.25 P. M.	1.26	.038	.73
77	7.40	1.26		
79	8.00	1.42	.032	.68
81	8.15	1.45		
83	8.35	1.42	.032	.71
86	9.10	1.40		
87	9.35	1.47	.030	.69
89	10.05	1.31		
91	10.25	1.63	.030	.76
93	10.50	1.49		
95	11.15	1.28	.030	.80
97	11.35	1.17		
99	12.00	1.40	.044	.70
2301	12.20 A. M.	1.40		
3	12.45	1.38	.040	.76
5	1.15	1.52		
7	1.30	1.47	.036	.74
9	1.50	1.47		
11	2.10	1.68	.032	.87
13	2.40	1.77		
15	3.05	1.59	.028	.68
17	3.50	1.63		
19	4.20	1.37	.032	.73
21	4.50	1.37		
24	5.15	1.28	.034	.82
26	5.35	1.52		
27	5.50	1.05	.038	.80

1464

FROM 6 A. M. 4-27 TO 6 A. M. 4-28. BESSEMER, APRIL 28, 1894.

2328	6.05 A. M.	1.00		
30	6.10	1.03	.036	.85
32	6.55	1.21		
34	7.10	1.31	.030	.89
36	7.40	1.26		
39	8.35	1.12	.038	.75
41	9.05	1.12		
43	9.25	1.07	.026	.70

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
45	9.50	1.14		
47	10.15	1.03	.022	.63
49	10.35	.84		
51	10.55	.89	.028	.75
53	11.20	1.17		
55	11.45	1.21	.026	.81
57	12.10 P. M.	1.54		
59	12.40	1.45	.034	.84
61	1.05	1.40		
63	1.30	1.54	.024	.74
65	1.45	1.40		
67	2.05	1.45	.018	.73
69	2.20	1.31		
71	2.40	1.24	.018	.76
74	3.15	1.14		
78	3.55	1.40	.030	.98
80	4.40	1.45		
83	5.10	1.28	.024	.81
85	6.10	1.33		
87	6.40	1.05	.036	.80
89	6.55	1.14		
91	7.15	1.21	.032	.77
93	7.50	1.28		
95	8.15	1.19	.028	.78
97	8.30	1.12		
98	8.50	1.82	.028	1.04
2401	9.15	1.45		
3	9.40	1.47	.039	.77
4	10.00	1.31		
6	10.25	1.17	.038	.85
9	10.55	1.19		
11	11.15	1.26	.042	.81
12	11.30	1.33		
15	11.45	1.14	.031	1.02
17	12.30 A. M.	1.31		
19	12.50	1.33	.030	.78
1465				
22	1.30	1.42		
24	1.50	1.24	.030	.73
26	2.05	1.14		
27	2.25	.93	.036	.72
29	2.40	.93		
31	3.00	.93	.036	.76
35	3.15	1.24		
36	3.45	1.38	.046	.92
37	4.10	1.24		
39	4.55	1.42	.034	.81
41	5.30	1.42		

FROM 6 A. M. 4-28 TO 6 A. M. 4-30. BESSEMER, APRIL 30, 1894.

Blow No.	Time.	Silicon.	Sulphur.	Manganese.
2444	6.05 A. M.	1.35	.038	.90
46	6.20	1.31		
47	6.55	1.31	.024	.73
49	7.20	1.35		
51	7.40	1.26	.022	.71
53	8.10	1.21		
56	9.00	1.03	.028	.68
58	9.25	1.03		
60	9.55	1.31	.026	.84
62	10.25	1.26		
64	10.55	1.17	.032	.75
66	11.25	.98		
68	11.45	1.07	.028	.60
70	12.15 P. M.	1.03		
72	12.35	.98	.033	.62
74	1.05	1.03		
77	2.00	1.59	.036	.70
2482	6.20	1.73		
86	6.50	1.63	.032	.80
88	7.40	1.54		
90	8.05	1.31	.028	.64
92	8.25	1.35		
94	8.35	1.35	.024	.79
96	9.00	1.33		
98	9.25	1.38	.024	.70
2500	9.50	1.31		
2	10.15	1.24	.033	.72
4	11.25	1.24		
6	11.45	1.33	.038	.80
10	12.15 A. M.	1.19		
12	12.35	1.33	.042	.68
14	1.15	1.42		
16	1.25	1.38	.032	.70
1466				
18	1.50	1.24		
20	2.15	1.33	.028	.64
22	3.00	1.28		
24	3.25	1.26	.028	.67
26	3.45	1.26		
28	4.30	1.31	.029	.65
30	4.35	1.31		
32	5.15	1.21	.035	.60
34	5.25	1.38		
36	5.30	1.40	.040	.70

1467 *Analyses of the Steel Casts of Pig Iron Made at Each Furnace, Edgar Thomson Works, April*, 1894.

The Carnegie Steel Company, Limited.

Laboratory of the Edgar Thomson steel works.

BESSEMER, APRIL 3, 1894.

Lab'y No. or time of cast.	Fce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
11.15 A. M.	B	4–2	1	17		.048	3–31	.089		90
4.20 P. M.			1	96		.014				
9.35			1	70		.022				
2.50 A. M.		4–3	1	31		.041				
						.041				
9.25 A. M.	C	4–2	2	19		.016	"	.091		86
						.016				
2.35 P. M.			1	49		.021				
7.10			1	93		.017				
1.10 A. M.		4–3	1	10		.029				
6.40			1	91		.016				
7.00 A. M.	D	4–2	1	40		.029	"	.096		86
12.35 P. M.			1	44		.045				
5.30			1	42		.045				
11.10 A. M.			1	61		.041				
4.45 A. M.		4–3	1	28		.034				
8.45 A. M.	E	4–2	1	82		.019	"	.090	1	00
2.00 P. M.			1	68		.031				
8 35			2	80		.019				
						.019				
						.019				
2.35 A. M.		4–3	1	61		.029				
						.029				
10.30 A. M.	F	4–2		44		.016	"	.089		96
						.016				
4.55 P. M.			1	23		.016				
						.017				
10.30			1	21		.031				
						.031				
4.20 A. M.		4–3		70		.034				
						.034				
8.28 A. M.	G	4–2	1	47		.009	"	.087	1	00
						.017				
2.02 P. M.			1	56		.011				
						.014				
1468										
9.00			1	37		.012				
						.012				
2.45 A. M.		4–3	1	26		.024				
						.026				

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.00.
12.20 P. M.	H	4-2	1	12	.024	"	.094	1	04	
					.024					
6.25			2	01	.022					
12.25 A. M.		4-3	1	31	.024					
					.026					
6.09				98	.031					
					.031					
10.20 A. M.	I	4-2	1	47	.016	"	.100	1	20	
					.014					
3.25 P. M.			1	40	.019					
9.05			1	82	.024					
3.05 A. M.			1	03	.036					
					BESSEMER, APRIL 4, 1894.					
8.50 A. M.	B	4-3		72	.043	4-2	.091		80	
2.40 P. M.				46	.084					
7.40			1	09	.056					
12.40 A. M.		4-4	1	24	.110					
6.10			1	24	.026					
11.00				88	.129					
11.45 A. M.	C	4-3	1	30	.024	"	.086		80	
4.30 P. M.			1	19	.031					
10.00			1	89	.022					
					.022					
3.25 A. M.		4-4		49	.048					
9.30			1	24	.016					
					.016					
10.45 A. M.	D	4-3	1	72	.028	"	.098		86	
4.00 P. M.			1	88	.022					
8.55			2	08	.024					
2.50 A. M.		4-4	1	47	.041					
7.15				86	.048					
8.15 A. M.	E	4-3		65	.051	"	.095		90	
1.20 P. M.			1	56	.043					
6.45			1	21	.053					
11.55			2	10	.046					
5.45 A. M.		4-4	1	87	.024					
10.00 A. M.	F	4-3		74	.028	"	.092		90	
					.026					
3.35 P. M.				86	.029					
					.029					
					.031					
1469										
9.35				95	.024					
					.029					
2.55 A. M.		4-4		77	.026					
					.026					
9.50				72	.028					
					.040					

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
8.15 A. M.	G	4–3	1	61	.021		"	.091		80
12.35 P. M.				88	.024					
					.028					
6.35			1	09	.022					
					.022					
12.25 A. M.		4–4		61	.022					
					.024					
5.45 A. M.			1	00	.026					
					.026					
11.25 A. M.	H	4–3		72	.036		"	.100	1	10
					.036					
5.25 P. M.			1	28	.036					
11.00			1	21	.031					
4.30 A. M.		4–4	1	61	.022					
10.45				35	.050					
					.052					
9.50 A. M.	I	4–3	1	82	.019		4–2	.099	1	08
					.121					
					.019					
2.17 P. M.			1	70	.014					
7.52			2	10	.017					
					.017					
1.40 A. M.		4–4	1	77	.026					
7.15			1	65	.048					
					BESSEMER, APRIL 7, 1894.					
9.00 A. M.	C	4–6		81	.050		4–5	.091		74
2.50 P. M.				89	.042					
8.40			2	10	.040					
1.35 A. M.		4–7	1	54	.024					
6.30			1	23	.031					
12.45 P. M.	D	4–6	1	54	.028		"	.094		80
					.026					
6.25			1	49	.026					
11.55			1	35	.028					
5.45 A. M.		4–7	1	68	.019					
					.022					
5.20 P. M.	E	4–6	1	87	.055		"	.098		86
11.20			1	82	.064					
4.55 A. M.		4–7	1	47	.046					
2.00 P. M.	F	4–6		84	.019		"	.099		92
					.017					
1170										
8.20				56	.017					
					.019					
					.015					
1.45 A. M.		4–7		61	.022					
					.022					
2.58 P. M.	G	4–6	1	91	.013		"	.089		86
					.013					

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.00.
8.50			1	40	.018					
					.015					
2.25 A. M.		4–7	1	03	.019					
					.022					
1.40 P. M.	H	4–6	1	45	.028	"	.100		110	
7.35			1	73	.026					
12.55 A. M.		4–7	1	94	.022					
6.40			1	77	.029					
					.029					
11.10 A. M.	I	4–6	1	30	.030	"	.092		120	
					.033					
4.20 P. M.				98	.030					
10.00				84	.019					
2.55 A. M.		4–7	1	14	.041					
					BESSEMER, APRIL 9, 1894.					
10.50 A. M.	C	4–7	1	42	.017	4–6	.091		70	
4.05 P. M.			2	66	.019					
					.019					
8.45			1	59	.041					
					.038					
1.40 A. M.		4–8	2	80	.024					
					.024					
6.30			2	85	.013					
					.013					
11.50 A. M.	D	4–7	1	54	.026	"	.089		80	
					.024					
5.35 P. M.			1	84	.024					
					.026					
11.30 P. M.			2	03	.031					
					.029					
5.40 A. M.		4–8	2	17	.018					
					.015					
10.25 A. M.	E	4–7	2	49	.029	"	.091		90	
3.15 P. M.			2	66	.037					
					.033					
8.40			2	33	.031					
					.029					
2.30 A. M.		4–8	1	80	.057					
					.057					
7.40 A. M.	F	4–7		67	.026	"	.101		90	
					.019					
1471										
12.40 P. M.			1	07	.022					
6.55			1	10	.017					
					.019					
1.10 A. M.		4–8	1	14	.013					
					.015					

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
8.20 A. M.	G	4–7	1	21	.022		"	.089	90	
					.017					
1.33 P. M.			1	45	.015					
					.015					
7.50			1	07	.019					
					.017					
1.35 A. M.		4–8	1	03	.018					
					.022					
12.18 P. M.	H	4–7	1	33	.028		"	.095	106	
					.033					
5.30			1	19	.041					
					.037					
10.55			1	52	.035					
					.035					
4.40 A. M.		4–8	1	42	.029					
					.029					
855. A. M.	I	4–7	1	61	.022		"	.094	100	
1.40 P. M.			1	66	.017					
6.40			1	59	.015					
					.017					
11.55			1	33	.026					
					.026					
5.15 A. M.		4–8	1	59	.015					
					.015					
					BESSEMER, APRIL 9, 1894.					
11.05 A. M.	C	4–8	2	57	.033					
					.026					
3.45 P. M.			2	24	.020					
9.00			1	98	.020					
					.018					
1.45 A. M.		4–9	2	64	.013					
11.15 A. M.	D	4–8	2	52	.015					
					.013					
5.15 P. M.			2	24	.037					
					.035					
11.15			1	45	.057					
6.00 P. M.		4–9	2	03	.037					
					.039					
8.05 A. M.	E	4–8	3	17	.029					
					.026					
12.50 P. M.			3	27	.015					
					.015					
1472										
6.30			2	47	.031					
12.30 P. M.		4–9	2	54	.015					
7.25			2	50	.017					
					.017					
7.05 A. M.	F	4–8	1	21	.013					
					.013					

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon Per ct. .000.	Sulphur. Per ct. .000.	Phosphorus. Per ct. .000.	Manganese. Per ct. .00.
1.10 P. M.			2 01	.013		
				.013		
7.45			1 14	.033		
				.035		
1.45 A. M.		4–9	1 14	.022		
				.022		
7.35 A. M.	G	4–8	1 12	.015		
				.018		
2.25 P. M.			1 54	.011		
				.011		
8.00			1 25	.024		
				.022		
2.02 A. M.		4–9	89	.013		
				.018		
10.10 A. M.	H	4–8	1 96	.018		
				.022		
3.54 P. M.			2 47	.020		
				.013		
9.40			1 77	.028		
2.55 A. M.		4–9	1 80	.024		
				.026		
11.05 A. M.	I	4–8	1 87	.024		
				.026		
4.05 P. M.			2 10	.020		
10.37			2 05	.015		
				.015		
4.26 A. M.		4–9	1 77	.033		
				BESSEMER, APRIL 10, 1894.		
7.15 A. M.	C	4–9	2 01	.020	4–7	.087 70
				.020		
10.55			2 75	.013		
4.20 P. M.			2 57	.015		
				.017		
9.00			2 38	.017		
				.017		
2.00 A. M.		4–10	2 25	.017		
				.015		
6.50			2 43	.015		
11.40 A. M.	D	4–9	1 68	.035	"	.091 78
5.05 P. M.			1 63	.046		
10.00			1 21	.046		
				.048		
1473						
2.50 A. M.		4–10	1 31	.044		
9.40			1 35	.018		
1.00 P. M.	E	4–9	2 33	.029	"	.092 94
7.00			2 01	.022		

Lab'y No. or time of cast.	Furn.	Cast No. or date of cast.	Silicon. Per ct. .000.	Sulphur. Per ct. .000.	Phosphorus. Per ct. .000.	Manganese. Per ct. .000.
12.15 A. M.		4–10	1 56	.050		
6.20			1 35	.048		
8.15 A. M.	F	4–9	1 87	.013	" .098	86
				.013		
2.15 P. M.			2 01	.015		
7.55			1 35	.015		
2.00 A. M.		4–10	1 26	.026		
8.10			1 35	.020		
				.020		
7.55 A. M.	G	4–9	1 61	.015	" .092	86
				.017		
1.10 P. M.			1 61	.020		
				.020		
6.00			1 73	.017		
11.05			1 26	.017		
4.45 A. M.		4–10	1 45	.029		
10.16			1 47	.026		
				.024		
8.35 A. M.	H	4–9	2 08	.017	" .097	1 04
3.10 P. M.			2 21	.024		
8.55			1 07	.031		
2.50 A. M.		4–10	1 31	.031		
8.20			1 98	.020		
9.50 A. M.	I	4–9	2 12	.017	" .096	1 06
				.017		
2.33 P. M.			2 68	.013		
7.15			2 28	.013		
				.013		
12.30 A. M.		4–10	2 15	.013		
				.013		
6.12			1 61	.035		
				.035		

1474 BESSEMER, APRIL 11, 1894.

12.45 P. M.	C	4–10	1 68	.035	4–9 .083	86
6.35			1 79	.033		
11.10			1 49	.033		
4.35 A. M.		4–11	1 82	.035		
9.40			2 33	.024		
				.024		
3.50 P. M.	D	4–10	1 73	.037	" .084	1 00
9.45			1 91	.048		
2.40 A. M.		4–11	1 45	.066		
8.10			1 54	.060		
12.05 P. M.	E	4–10	1 56	.066	" .089	1 00
6.30			1 32	.074		
12.00			1 35	.066		
5.25 A. M.		4–11	1 91	.055		
10.15			1 91	.048		

Lab'y No. or time of cast.	P'ce.	Cast No. or date of cast.	Silicon. Per ct. .000.	Sulphur. Per ct. .000.	Phosphorus. Per ct. .000.	Manganese. Per ct. .00.
2.15 P. M.	F	4–10	79	.018	" .092	90
				.018		
6.48			79	.024		
				.022		
12.27 A. M.		4–11	95	.024		
				.026		
6.05			98	.026		
				.026		
11.20			58	.022		
4.13 P. M.	G	4–10	88	.024	" .091	80
8.32			1 21	.024		
				.026		
1.20 A. M.		4–11	1 21	.026		
6.55			1 21	.024		
1.55 P. M.	H	4–10	1 91	.020	" .096	92
7.25			2 05	.024		
				.022		
1.03 A. M.		4–11	1 49	.024		
				.022		
6.32			1 98	.024		
				.020		
11.05 A. M.	I	4–10	1 24	.031	" .086	92
5.05 P. M.			1 59	.052		
10.45			2 47	.022		
3.55 A. M.		4–11	1 73	.026		
8.55			1 31	.033		
1475				BESSEMER, APRIL 12, 1894.		
2.30 P. M.	C	4–11	2 38	.022	4–10 .089	90
6.25			1 91	.024		
11.15			2 19	.035		
				.037		
2.50 A. M.		4–12	1 73	.037		
9.30			2 17	.022		
				.022		
1.25 P. M.	D	4–11	1 96	.018	" .087	80
7.25			2 36	.040		
1.30 A. M.		4–12	2 19	.035		
				.035		
7.00			2 45	.033		
				.033		
3.15 P. M.	E	4–11	2 43	.030	" .091	90
9.00			1 87	.061		
2.50 A. M.		4–12	1 40	.064		
9.00			1 77	.051		
5.05 P. M.	F	4–11	79	.028	" .092	84
11.05			65	.044		
4.50 A. M.		4–12	1 35	.033		
				.035		

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
10.25				91	.044					
12.10 P. M.	G	4–11	1	12	.040		"	.091		86
5.45			1	12	.038					
11.50			1	14	.037					
6.00 A. M.		4–12	1	26	.048					
12.15 P. M.	H	4–11	1	66	.022		"	.097		94
					.020					
4.50			1	59	.033					
10.55			1	68	.028					
					.026					
5.00 A. M.		4–12	1	63	.033					
					.035					
1.47 P. M.	I	4–11	1	10	.037		"	.091		92
8.15			1	66	.038					
2.20 A. M.		4–10	1	35	.028					
7.48			1	14	.053					
1476					BESSEMER, APRIL 13, 1894.					
3.30 P. M.	C	4–12	1	42	.040		4–11	.089		74
9.35			2	07	.035					
					.035					
2.00 A. M.		4–13	2	84	.013					
					.013					
1.10 P. M.	D	4–12	1	31	.084		"	.086		74
7.55			2	17	.042					
1.45 A. M.		4–13	2	03	.037					
3.05 P. M.	E	4–12	1	63	.090		"	.096		80
9.00			2	68	.037					
2.45 A. M.		4–13	1	35	.095					
4.30 P. M.	F	4–12	1	14	.033		"	.091		80
					.037					
10.30			1	24	.042					
					.040					
2.50 A. M.		4–13	1	07	.048					
12.20 P. M.	G	4–12	1	40	.035		"	.096		94
6.05			1	21	.040					
					.037					
11.40			1	23	.031					
					.031					
5.23 A. M.		4–13	1	40	.024					
					.024					
11.30 A. M.	H	4–12	1	59	.042		"	.089		90
5.30 P. M.			1	24	.037					
11.25			1	40	.040					
					.037					
5.00 A. M.		4–13	1	87	.024					
2.00 P. M.	I	4–12	1	24	.040		"	.085		86
7.22			1	12	.063					
12.35 A. M.		4–13	1	82	.031					
6.10			1	51	.042					

BESSEMER, APRIL 14, 1894.

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
1.35 P. M.	C	4-13	1	42	.031		4-12	.091		70
7.05			2	43	.024					
					.026					
11.55			1	47	.022					
5.25 A. M.		4-14	1	31	.040					
12.45 P. M.	D	4-13	1	87	.040		"	.088		86
					.040					
6.30			1	52	.037					
11.55			1	75	.024					
					.028					
1477										
5.30 A. M.		4-14	1	63	.024					
					.022					
2.25 P. M.	E	4-13	2	05	.044		"	.090		80
8.05			1	68	.059					
1.45 A. M.		4-14	1	56	.061					
7.45			1	77	.044					
3.35 P. M.	F	4-13		65	.061		"	.096		86
9.35			1	03	.055					
2.45 A. M.		4-14		98	.042					
11.15 A. M.	G	4-13	1	31	.015		"	.094		90
					.018					
4.23 P. M.			1	87	.026					
10.25			1	31	.026					
					.026					
6.10 A. M.		4-14	1	35	.035					
10.58 A. M.	H	4-13	1	40	.015		"	.094	1	08
3.45 P. M.			1	42	.037					
					.035					
9.15			1	73	.022					
					.026					
2.35 A. M.		4-14	1	77	.022					
					.024					
11.45 A. M.	I	4-13	1	03	.151		"	.097		98
5.20 P. M.			1	05	.042					
11.00			1	31	.026					
4.20 A. M.		4-14	2	15	.022					
					.024					

BESSEMER, APRIL 16, 1894.

10.00 A. M.	C	4-15	1	52	.026					
					.026					
2.25 P. M.			1	73	.024					
					.022					
7.08			1	66	.022					
12.10 A. M.		4-16	1	47	.046					
5.20			1	14	.044					
8.55 A. M.	D	4-15	2	57	.020					
					.020					

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct. .000.	Sulphur. Per ct. .000.	Phosphorus. Per ct. .000.	Manganese. Per ct. .000.
2.40 P. M.			2 94	.020		
				.018		
8.25			1 98	.029		
				.031		
2.25 A. M.		4–16	1 80	.026		
				.024		
10.15 A. M.	E	4–15	2 45	.018		
				.018		
1478						
3.45 P. M.			2 43	.024		
9.15			1 33	.033		
				.033		
2.55 A. M.		4–16	1 68	.042		
				.040		
7.55 A. M.			1 49	.042		
7.30 A. M.	F	4–15	1 28	.024		
				.024		
1.40 P. M.			1 68	.020		
				.020		
6.25			1 45	.022		
				.020		
12.40 A. M.		4–16	1 59	.018		
				.018		
6.25			1 73	.018		
				.020		
2.48 P. M.	G	4–15	1 35	.024		
				.026		
8.25			1 40	.029		
				.026		
2.20 A. M.		4–16	1 47	.022		
				.024		
6.52 A. M.	H	4–15	1 80	.026		
				.026		
12.30 P. M.			1 66	.026		
				.029		
5.20			1 31	.022		
11.15			1 21	.024		
5.17 A. M.		4–16	1 77	.022		
				.022		
10.20 A. M.	I	4–15	1 45	.018		
				.018		
4.25 P. M.			1 49	.020		
10.00			2 08	.018		
4.00 A. M.		4–16	69	.035		
				BESSEMER, APRIL 17, 1894.		
10.50 A. M.	C	4–16	1 68	.042	4–14 .089	70
				.037		
4.15 P. M.			1 26	.088		
10.00			82	.143		

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
4.30 A. M.		4–17	1	77	.031					
9.50			1	07	.059					
8.30 A. M.	D	4–16	1	93	.026		"	.090		94
					.026					
2.45 P. M.			1	87	.022					
					.020					
1479										
8.30			1	70	.022					
					.022					
2.35 A. M.		4–17	1	59	.031					
8.25			1	75	.024					
					.022					
12.35 P. M.	E	4–16	2	24	.042		"	.087		94
6.30			2	57	.033					
12.25 A. M.		4–17	2	52	.033					
7.05			2	83	.037					
					.035					
11.55 A. M.	F	4–16	1	35	.022		"	.095		86
					.026					
4.50 P. M.				93	.029					
					.029					
11.25			1	47	.018					
					.020					
5.45 A. M.		4–17		49	.070					
11 05				89	.029					
8.20 A. M.	G	4–16	1	21	.040		"	.096		124
					.044					
1.25 P. M.			1	21	.040					
7.26			1	03	.040					
					.042					
2.15 A. M.		4–17	1	17	.035					
7.32			1	07	.033					
					.031					
11.08 A. M.	H	4–16	1	75	.026		"	.097		84
					.026					
5.10 P. M.				96	.029					
11.10			1	38	.026					
					.028					
5.15 A. M.		4–17	1	61	.027					
					.025					
11.05			1	98	.017					
					.022					
9.40 A. M.	I	4–16		67	.026		"	.090		84
3.32 P. M.				75	.026					
9.05			1	07	.024					
					.026					
2.55 A. M.				96	.029					
					.031					
8.55				77	.020					

BESSEMER, APRIL 18, 1894.

Lab'y No. or time of cast.	Fce.	Cast No. or date of cast	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
1480										
2.55 P. M.	C	4-17	1	54	.025		4-16	.094		56
8.47			1	70	.037					
2.30 A. M.		4-18	1	21	.037					
7.15			1	51	.039					
2.15 P. M.	D	4-17	2	12	.031		"	.089		80
					.029					
7.55			1	59	.022					
					.022					
1.50 A. M.		4-18	1	28	.024					
					.024					
8.55			1	45	.039					
					.039					
12.25 P. M.	E	4-17	2	05	.037		"	.087		84
5.15			2	03	.044					
11.35			1	89	.057					
5.05 A. M.		4-18	2	24	.031					
4.05 P. M.	F	4-17	1	03	.020		"	.097		84
					.017					
10.10				96	.051					
					.029					
2.50 A. M.		4-18		91	.031					
9.05			1	09	.030					
1.00 P. M.	G	4-17	1	03	.017		"	.095		96
					.015					
6.35			1	21	.055					
					.059					
11.15			1	31	.029					
					.029					
2.55 A. M.		4-18	1	05	.024					
					.022					
4.34 P. M.	H	4-17	2	19	.017		"	.092		84
					.017					
10.47			1	77	.018					
					.018					
2.55 A. M.		4-18	2	03	.022					
					.023					
9.00			1	47	.021					
					.021					
1.30 P. M.	I	4-17	1	19	.033		"	.100	1	.38
6.55			1	66	.017					
					.020					
12.48 A. M.			1	35	.022					
6.30			1	17	.022					
					.022					

BESSEMER, APRIL 19, 1894.

1481										
1.05 P. M.	C	4-18	2	03	.035		4-17	.092		57
6.25			1	77	.032					

Lab'y No. or time of cast.	Pcc.	Cast No. or date of cast.	Silicon. Per ct.	.00.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.00.
12.15 A. M.		4–19		98	.062					
6.10			1	26	.052					
					.052					
3.00 P. M.	D	4–18	1	33	.039	"	.089		64	
9.25			1	14	.025					
2.55 A. M.		4–19	1	26	.029					
8.40			1	42	.044					
					.039					
10.35 P. M.	E	4–18	2	06	.069	"	.081		86	
4.40			1	87	.041					
10.20			1	68	.044					
4.30 A. M.		4–19	1	42	.036					
10.45			1	49	.050					
					.050					
2.30 P. M.	F	4–18	1	23	.025	"	.089		76	
8.10			1	14	.014					
					.016					
1.50 A. M.		4–19	1	38	.034					
					.034					
7.55			1	28	.023					
					.023					
10.03 A. M.	G	4–18	1	28	.032	"	.086		1	22
					.032					
4 00 P. M.			1	10	.032					
					.030					
9.30			1	14	.034					
					.036					
2.53 A. M.		7–19	1	42	.032					
					.034					
9.00			1	05	.050					
2.15 P. M.	H	4–18	1	68	.021	"	.093		90	
					.023					
7.30			1	59	.023					
1.30 A. M.		4–19	1	63	.032					
7.25			1	33	.023					
					.024					
11.50 A. M.	I	4–18	1	37	.018	"	.100		94	
5.27 P. M.			1	14	.028					
11.25				65	.029					
5.13		7–19		96	.032					
1482					BESSEMER, APRIL 20, 1894.					
12.05 P. M.	C	4–19		47	.150	4–18	.090		60	
4.40				82	.078					
10 00			1	10	.048					
2.45 A. M.		4–20	1	21	.037					
8.15			1	03	.085					
2.50 P. M.	D	4–19	1	77	.030	"	.091		68	
					.035					

Lab'y No. or time of cast.	Furnace.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
8.00			2	01	.019					
1.45 A. M.		4–20	1	96	.021					
7.25			1	88	.028					
4.30 P. M.	E	4–19	2	29	.032	"	.093	1	00	
11.10			1	49	.046					
4.40 A. M.		4–20		79	.064					
1.30 P. M.	F	4–19	1	07	.025	"	.089		88	
					.023					
6.55				72	.025					
					.021					
12.30 A. M.		4–20		58	.032					
					.032					
6.30				79	.030					
					.032					
1.57 P. M.	G	4–19		98	.039	"	.085	1	08	
					.037					
7.32				70	.035					
					.037					
1.15 A. M.		4–20		93	.037					
					.039					
6.30			1	26	.030					
					.023					
12.53 P. M.	H	4–19	1	28	.030	"	.087		86	
6.10			1	49	.021					
12.13 A. M.		4–20	1	54	.028					
6.07			1	63	.023					
11.30 A. M.	I	4–19		81	.032	"	.094	1	24	
4.07 P. M.				77	.030					
					.030					
9.30			1	24	.025					
2.55 A. M.		4–20	1	00	.025					
9.00			1	40	.023					
					.025					
					BESSEMER, APRIL 21, 1894.					
1483										
1.05 P. M.	C	4–20		75	.085	4–19	.096		58	
6.40			1	87	.021					
12.40 A. M.		4–21	1	80	.023					
6.00			1	40	.025					
11.35 A. M.	E	4–20	1	91	.048	"	.087		94	
5.35 P. M.			1	84	.032					
1.35			1	70	.048					
4.35 A. M.		4–21	1	70	.048					
11.15 A. M.	F	4–20		79	.028	"	.092	1	00	
					.030					
					.032					
4.40 P. M.				56	.032					
					.035					
10.20				75	.032					

Lab'y No. or time of cast.	Fce.	Cast No. or date of cast.	Silicon. Per ct. .000.	Sulphur. Per ct. .000.	Phosphorus. Per ct. .000.	Manganese. Per ct. .000.
4.20 A. M.		4–21	98	.025		
				.025		
12.15 P. M.	G	4–20	93	.042	" .092	1 30
				.044		
6.00			93	.037		
				.037		
12.05 A. M.		4–21	93	.039		
				.037		
5.30			96	.028		
				.030		
10.00 A. M.	H	4–20	1 59	.021	" .098	0 84
3.27			1 68	.023		
8.50			1 87	.023		
2.35 A. M.		4–21	1 66	.025		
2.25 P. M.	I	4–20	1 23	.023	" .090	1 16
7.40			1 31	.018		
1.30 A. M.		4–21	1 40	.028		
7.15			1 26	.023		
	D				" .094	58
				BESSEMER, APRIL 23, 1894.		
10.35 A. M.	C	4–21	2 01	.014	4–20 .100	48
				.014		
3.15 P. M.			2 42	.014		
				.014		
1.45			2 01	.014		
				.016		
12.55 A. M.		4–22	2 52	.016		
				.014		
5.55			3 22	.012		
				.012		
4.10 P. M.	D	4–22	98	.032	"	68
1484						
10.15 A. M.	E	4–21	2 42	.039	" .096	92
4.13 P. M.			2 40	.030		
				.032		
9.45			2 01	.019		
				.021		
2.50 A. M.		4–22	1 35	.037		
				.037		
9.55 A. M.	F	4–21	1 35	.025	" .089	1 00
				.025		
2.30 P. M.			96	.039		
				.038		
8.20 A. M.			1 28	.041		
				.041		
1.50 A. M.		4–22	1 77	.019		
				.019		

Ladle No. or time of cast.	Furnace.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
1.50			1	24	.021					
					.052					
11.12 A. M.	G	4–21	1	07	.042		"	.098	1	26
					.044					
4.50 P. M.				93	.032					
					.032					
10.30			1	26	.030					
					.032					
2.55 A. M.		4–22	1	35	.030					
					.035					
9.55			1	56	.026					
					.029					
1.44 P. M.	H	4–21	1	31	.028		"	.095		83
					.028					
7.30			1	49	.028					
					.028					
1.30 A. M.		4–22	1	59	.025					
					.023					
7.15			1	75	.025					
					.025					
12.10 P. M.	I	4–21	1	45	.018		"	.096	1	04
5.38			1	50	.025					
					.030					
10.20			1	35	.019					
					.021					
2.55 A. M.		4–22	1	35	.025					
					.025					

10.55 A. M.	C	4–22	2	15	.014					
					.014					
3.42 P. M.			1	80	.012					
9.10			2	31	.012					
2.10 A. M.		4–23	2	19	.012					
7.45 P. M.	D	4–22		67	.086					
10.15				61	.057					
12.50 A. M.		4–23	1	07	.032					
3.55			1	17	.032					
6.05			1	10	.034					
7.10 A. M.	E	4–22	2	12	.044					
					.037					
12.25 P. M.			1	56	.044					
					.045					
6.10			3	31	.030					
12.05 A. M.		4–23	3	41	.018					
5.20			1	63	.042					
12.20 P. M.	F	4–22	1	33	.020					
					.019					

Lab'y No or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
7.15			1	17	.023					
					.023					
1.10 A. M.		4–23	1	26	.025					
					.025					
6.45			1	17	.020					
					.023					
3.40 P. M.	H	4–22	1	26	.032					
					.030					
9 30			1	31	.023					
					.023					
2.50 A. M.		4–23	1	17	.032					
					.030					
12.27 P. M.	H	4–32	1	49	.028					
					.025					
5.20			1	63	.030					
11.00			1	54	.018					
3.45 A. M.		4–23	1	73	.025					
8.52			1	80	.030					
8.40 A. M.	I	4–22	1	38	.023					
					.023					
2.27 P. M.			1	42	.016					
					.014					
7.27			1	61	.023					
1.20 A. M.		4–23	1	21	.032					
					.030					
6.32			1	52	.028					
11.10			1	68	.044					
1486					BESSEMER, APRIL 27, 1894.					
12.45 P. M.	C	4–26	1	03	.046	4–21	.102		94	
6.25			2	10	.024					
12.20 A. M.		4–27	2	08	.016					
					.026					
6.00			1	40	.030					
11.00			1	98	.020					
12.20 P. M.	D	4–26	1	38	.024	"	.090		84	
4.35			1	77	.012					
8.15			2	42	.014					
11.55			1	75	.018					
3.45 A. M.		4–27	1	45	.016					
					.014					
7.50			1	75	.020					
					.020					
10.50 A. M.	E	4–26	1	45	.032	"	.094		94	
5.20 P. M.			1	55	.044					
11.05			1	73	.066					
5.20 A. M.		4–27	1	84	.038					
10.15			2	03	.038					
2.20 P. M.	F	4–26		84	.027	"	.088		86	

Lab'y No. or time of cast.	Fce.	Cast No. or date of cast.	Silicon. Per ct. .000.	Sulphur. Per ct. .000.	Phosphorus. Per ct. .000.	Manganese. Per ct. .000.
8.15			98	.026		
				.028		
2.10 A. M.		4–27	1 35	.036		
				.038		
7.30			1 26	.022		
11.45 A. M.	G	4–26	1 14	.022	" .095	1 10
				.024		
5.05 P. M.			1 14	.022		
11.10			1 42	.024		
				.024		
5.10 A. M.		4–27	1 45	.022		
				.022		
10.48			1 00	.022		
				.032		
1.30 P. M.	H	4–26	1 68	.020	" .097	76
				.022		
7.25			1 87	.016		
1.15 A. M.		4–27	2 15	.020		
7.10			1 59	.016		
				.020		
3.40 P. M.	I	4–26	1 56	.022	" .103	1 00
9.45			1 56	.030		
2.50 A. M.		4–27	75	.028		
9.55			91	.027		
1487				BESSEMER, APRIL 28, 1894.		
4.15 P. M.	C	4–27	2 33	.010	4–27 .100	84
				.010		
9.55			2 33	.012		
				.014		
2.50 A. M.		4–28	1 82	.018		
9.00			2 57	.016		
				.018		
11.45 A. M.	D	4–27	1 61	.018	" .092	84
3.25 P. M.			1 82	.008		
7.10			2 05	.010		
10.55			1 89	.016		
2.50 A. M.		4–28	1 68	.020		
6.45			1 77	.016		
2.40 P. M.	E	4–27	1 89	.038	" .090	1 10
8.45			1 87	.048		
2.45 A. M.		4–28	1 82	.036		
8.25			1 82	.064		
1.00 P. M.	F	4–27	1 14	.028	" .089	90
				.028		
6.10			98	.022		
				.018		
11.50			1 56	.020		
5.20 A. M.		4–28	1 24	.028		

Lab'y No. or time of cast.	F'ce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
5.00 P. M.	G	4–27	1	07	.036	"	.097	1	18
					.032					
10.45			1	12	.030					
					.030					
4.42 A. M.		4–28	1	17	.034					
					.034					
12.35 P. M.	H	4–27		98	.020	"	.100		74
6.05			1	31	.026					
12.35 A. M.		4–28	1	33	.024					
6.10			1	31	.036					
2.15 P. M.	I	4–27		91	.022	"	.100	1	00
					.022					
8.25				89	.024					
1.55 A. M.		4–28		65	.036					
7.18				91	.034					
1488					BESSEMER, APRIL 30, 1894.					
2.20 P. M.	C	4–28	2	38	.018	4–27	.092		86
					.018					
6.55			2	29	.018					
					.018					
12.15 A. M.		4–29	2	12	.016					
					.018					
4.40			2	17	.014					
					.016					
9.35			2	33	.024					
					.026					
10.55 A. M.	D	4–28	1	77	.022	"	.092		88
					.020					
2.45 P. M.			2	01	.014					
7.10			1	77	.016					
11.00			1	03	.014					
2.50 A. M.		4–29	1	42	.020					
					.018					
7.20			1	96	.012					
					.012					
1.00 P. M.	E	4–28	1	80	.056	"	.098	1	16
6.10			2	10	.044					
					.041					
11.10			1	91	.034					
					.036					
2.50 A. M.		4–29	2	78	.016					
					.020					
9.50			3	08	.018					
					.018					
10.55 A. M.	F	4–28	1	49	.018	"	.094		86
					.022					
3.20 P. M.			1	45	.018					
					.018					

Ladle No. or time of cast.	Fce.	Cast No. or date of cast.	Silicon. Per ct.	.000.	Sulphur. Per ct.	.000.	Phosphorus. Per ct.	.000.	Manganese. Per ct.	.000.
9.10			1	49	.020					
					.020					
2.50 A. M.		4–29	1	54	.016					
					.018					
8.55			1	68	.018					
					.024					
9.42 A. M.	G	4–28	1	10	.030	"	.092		1	00
					.032					
3.07 P. M.				98	.032					
					.034					
8.55				84	.050					
					.058					
2.30 A. M.		4–29	1	38	.028					
					.030					
1489										
10.50 A. M.	H	4–28	1	03	.035	"	.098			74
4.20 P. M.			1	03	.022					
					.028					
9.45			1	31	.022					
					.026					
2.50 A. M		4–29	1	24	.016					
					.020					
12.20 P. M.	I	4–28	1	05	.024	"	.103			84
					.024					
5.05			1	35	.012					
					.014					
10.45				98	.128					
					.132					
2.55 A. M.		4–29	1	07	.020					
					.018					
9.05			1	35	.014					
					.016					

1490 *The Development of American Blast Furnaces with Special Reference to Large Yields.*

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The development of blast-furnace practice in America in the direction of large yields is mainly the history of our working since the year 1880, as the advancement that has been made in the last decade is greater than that made in the previous quarter of a century. A new era in the manufacture of pig iron began in 1880 with the putting in blast of the Edgar Thomson furnaces. These furnaces at once leaped to the front as pig-iron producers, and have maintained that position—with but one brief interruption—ever since. I shall, therefore, confine myself mainly to a description of these works, showing the changes in design and practice by which

these results have been achieved. In order to show more clearly the progress that has been made since 1880, I shall refer briefly to the best work that was done in the ten years previous to that time. The Struthers furnace, in Ohio, was one of the first to attract attention in the matter of large outputs. This furnace was 55 feet high, 16 feet diameter of bosh, 9 feet hearth, stock line about 8 feet 6 inches. The fuel was raw coal. This furnace, in December, 1871, made 1,602 tons of iron, and in January, 1872, made 1,642 tons. The best output in a single week was 400 tons. By March, 1876, the product had increased to 2,032 tons. The furnace was blown by one engine, with an air cylinder 72 inches in diameter and 4-feet stroke. The only change made from 1871 to 1876 was the addition of a second blowing engine. The size of the hearth was much in advance of the construction usual at that time; and was, in fact, as large as would now be put in a furnace of the same size.

The good results obtained at this furnace were largely due
1491 to the fact that the manager, Mr. Thomas W. Kennedy, broke away from the traditional practice of regulating the quantity of blast by the pressure gauge, and substituted therefor the revolutions of the engine—a practice that obtains today.

A record of No. 1 furnace, of the Isabella furnaces, located at Pittsburgh, has been furnished me; and, as these furnaces have since become famous in the annals of pig-iron manufacture, a return of their work at that time will be found interesting. I have not been able to secure the lines or detail construction of this furnace, but the general dimensions were:—height, 75 feet; diameter of bosh, 20 feet; cubical capacity, about 15,000 feet. The furnace was "blown in" in January, 1876, and continued in blast until May, 1880—making a total output of 117,575 tons of pig iron, or an average of 2,264 tons per month. The consumption of coke per ton of iron averaged 3,000 lbs.; the temperature of blast ranged from 1,000 to 1,100 degrees, with a blast pressure of 4 to 6 lbs. No record was kept of the amount of air blown. The Lucy furnaces, owned by the firm of Carnegie, Phipps & Co., are also located in Pittsburgh. These furnaces ranked with the Isabella as the largest producers in America. I have been so fortunate as to obtain the lines of one of these furnaces, the Lucy No. 2, built in 1877, which I show in Fig. 1. The general dimensions are as follows:—Total height, 75 feet; diameter of bosh, 20 feet; diameter of hearth, 9 feet; cubical capacity, 15,400 feet. This drawing shows a bell 12 feet in diameter; but Mr. H. M. Curry, who was the manager of the works, advises me that the bell generally in use was 11 feet in diameter. During a part of the blast a bell 12 feet in diameter was tried, but not proving to be of advantage, was abandoned. In the construction of this furnace, the noticeable features are a narrower hearth and a wider top than are now put in furnaces of the same cubical capacity; but at that time it was considered an excellent shape, and certainly did produce some excellent re-

NOTE.—All tons are gross tons of 2,240 lbs., and all temperatures are Fahrenheit.

sults. As early as 1878 this furnace had made a monthly
1492 output of 3,286 tons, on a coke consumption of 2,793 lbs. per ton of iron; and in one week shortly afterwards made 821 tons. The furnace was "blown in" in September, 1877, but after running a few months was blown out in order to repair the bosh walls, which, for some reason, had rapidly given way. In the following March the furnace was again started, and continued in blast for nearly thirty-four months, making in this time an output of 92,128 tons, or an average of 2,737 tons per month, on an average coke consumption of 2,865 lbs. per ton of iron. For the first twelve months the output was 33,552 tons, on a coke consumption of 2,850 lbs. The amount of air blown was 16,000 cubic feet per minute, which entered the furnace through six 8-inch tuyeres; the temperature of blast was 915 degrees, and the pressure at tuyeres 5 lbs. The ore mixture yielded in the furnace 60 per ct. iron. The work that was done at this furnace was unquestionably the best, all things considered, that had been accomplished prior to the starting of the Edgar Thomson furnaces.

Furnace "A" of the Edgar Thomson works was originally a charcoal furnace at Escanaba, Michigan, but was removed and erected on its new foundations in 1879. The dimensions of this furnace, as will be seen by a reference to Fig. 2, are as follows: Height, 65 feet; diameter of bosh, 13 feet; diameter of hearth, 8 feet 6 inches; cubical capacity, 6,396 feet. Six tuyeres, 4 inches in diameter, were used; these, projecting 7 inches inside the crucible, made the efficient diameter of hearth 7 feet 4 inches. The tuyeres were placed 5 feet 6 inches above the hearth line. In vol. VIII of the "Transactions of the American Institute of Mining Engineers," a description is given of the "blowing in" and subsequent working of this furnace, by Mr. Julian Kennedy, who was then manager of the works. The following points of construction are emphasized in his paper. The interior lines make very small angles with each other—so small, in fact, that the arc of a circle drawn from the top to the tuyeres
1493 will not deviate more than two inches from the lines as given. Particular attention was given to rounding the angles. The bosh is located about midway in the furnace, making the bosh wall very steep. The batter of this wall was $1\frac{3}{8}$ inch to the foot, which is equivalent to an angle of 84 degrees. The furnace was lined throughout with small bricks. The stove equipment consisted of three Siemens-Cowper-Cochrane stoves 15 feet in diameter by 50 feet in height. This furnace was "blown in" in January, 1880. The ore mixture consisted of Tafna, M'Comber, Pilot Knob, and Somorrostro ores, yielding in the furnace 54.5 per cent iron. The output of the first full week was 442 tons, and reached 537 tons for the fourth week. The output and consumption of coke for the first few months are as follows:

Month.	Tons.	Lbs. coke per ton of iron.
January	1,634	2,675
February	2,236	2,306
March	2,762	2,306
April	1,586	2,482*
May	2,226	1,945

In June the furnace was changed to make spiegel, and has been used almost exclusively ever since for making the various grades of spiegel and ferro-manganese. The average weekly output for the month of March was 644½ tons, one day having been lost.

The best week's output was 671 tons. The blast was heated to an average temperature of 1,050 degrees, the utmost that the stoves would furnish; the pressure at the tuyeres was 6¼ pounds. The engine equipment consisted of two vertical blowing engines, one of which was new, with a blowing tub 84 inches in diameter, and 4 feet stroke; the other, a small and inefficient one, had been brought from Escanaba. But it so happened that furnace "B" was in course of construction, and one of the engines belonging to this furnace was in good running order; consequently, the Escanaba
1494 engine was retired from active service, and these two larger engines were used to supply furnace "A."

The volume of air forced into this furnace was 15,000 cubic feet per minute, or as much as was used elsewhere for furnaces of more than twice the capacity. The results obtained were surprising, and it is no wonder that the pig-iron-making world regarded them with astonishment amounting, in many cases, to incredulity. Considering the cubical capacity of the furnace, the rate of driving was certainly excessive; and that the results on fuel were so low, as compared with the subsequent consumption on larger furnaces where the same practice was employed, is mainly due to the narrow furnace stack. These fuel results, as I shall presently show, were much lower than any obtained from the larger furnaces in the next five years; and, had a distinction been then made between rapid driving on the one hand and excessive driving on the other, many American furnaces would have reduced their outlay for fuel enormously.

In Fig. 3 is shown a drawing of the second furnace erected at these works, of which the general dimensions are as follows:—Height, 80 feet; diameter of bosh, 20 feet; diameter of hearth, 11 feet; cubical capacity, 17,868 feet. The brick-work of the stack was held together by 8-inch iron bands supported by staves of T-iron, forming a crinoline. The bosh walls were banded in the same manner. The walls of the hearth were surrounded by solid cast-iron plates, securely bolted, no cooling plates of any kind being used. The stock was distributed at the top by a double bell, in which the central cone remained stationary; while the outer conical ring, being lowered, cast the stock towards the wall and centre of

* Furnace was stopped for four days.

the furnace. One feature of this construction, differing from that of other furnaces then using coke for fuel, was the large hearth, providing more space for combustion. As originally planned, the hearth was 9 feet in diameter at the bottom, and sloping up to the tuyeres; but, before building, Mr. Kennedy changed the
1495 plan, so that the inwalls of the hearth would be straight, making the diameter 11 feet. There was, moreover, an increased number of tuyeres, eight being used, and an increased elevation of tuyeres above the hearth level, all of which were necessary for rapid driving and large yields. In the anthracite district large hearths had been tried at a much earlier day. As early as 1854 the Thomases, at the Crane iron works, in the Lehigh valley, had tried enlarging their hearths by pulling back the tuyeres until a diameter of 11 feet was reached. From this experiment they obtained such excellent results, both as to output and quality of metal, that they afterwards adopted as a standard that the diameter of the hearth should be one-half the diameter of the bosh. But while the hearths of various furnaces had been enlarged after they were in blast, yet no American furnace up to that time had been constructed with so large a hearth as this one at the Edgar Thomson works. In another respect this furnace was well prepared by its designers for a high productive capacity, viz., in its equipment. Firebrick stoves of the most approved type were erected. Substantially-built blowing engines were provided, and they were rendered efficient by an ample supply of boilers—a point in which other furnaces were then sadly lacking. At the same time all the flues and mains were constructed sufficiently large, and in the most substantial way. In fact, no furnace previously erected had been planned on such a liberal basis; consequently, large yields were to be expected.

The furnace was put in blast in April, 1880. In the following month an output of 3,718 tons was made, and the next month showed 4,318 tons; thus fully justifying the claims of its designers by eclipsing all previous records. The detailed record of the work done by this furnace during the earlier months of the blast is as follows:

1496 Months.	Tons.	Lbs. coke per ton iron.
April	2,723	2,536
May	3,718	2,574
June	4,318	2,344
July	4,345	2,706
August	4,601	2,811
September	4,221	2,757
October	4,722	2,736

It will be noticed that the consumption of fuel increases as the summer months advance. These works, being located on flat land along the Monongahela river, are more particularly effected than elsewhere by the content of moisture in the atmosphere, it being nearly twice as much in summer as in winter. While this fact has

always had an important bearing on our fuel economy, yet, in this case, another feature of the practice tending to increase the fuel consumption was the increased rate of driving; the volume of air blown having been gradually increased to 30,000 cubic feet per minute, engine measurements, taxing alike the efficiency of the engines and the stoves. However, a high productive capacity was aimed at, and an output of 4,722 tons in a month was certainly marvelous at that time, and was either regarded as incredible or accounted for on the supposition that the furnace had been transformed into a cupola by melting large quantities of scrap. But the furnace records show that the yield of ore mixture was 55 per cent. iron. The weight of limestone was 25 per cent. of the weight of the ore. An analysis of the cinder shows:

	Per cent.
Silica	32.31
Alumina	13.20

The limestone contained a very small quantity of magnesia. The blast entered the furnace through eight bronze tuyeres of 5½ inches diameter, and was heated to a temperature of 1,100 degrees. The silicon in the iron averaged about 2 per cent. The rapid wear of the furnace walls, through the use of such a large volume of
1497 air, gradually increased the consumption of coke to over 3,000 lbs. per ton of iron. At the end of the first twelve full months the output was 48,179 tons, on an average coke consumption of 2,859 lbs. per ton of iron. The second year showed an average consumption of 3,200 lbs. of coke, with a decrease in yield. The upper brick-work of the stack having given way, the furnace was blown out after a blast of two years and five months, having made a total product of 112,060 tons, on an average coke consumption of 3,149 lbs. per ton of iron.

The results obtained in this blast determined several important changes in construction. It was seen that the crinoline structure afforded inadequate protection to the brick-work of the stack, in consequence of which it was torn down and replaced by an iron jacket; also, that the bosh walls should be protected so as to preserve as far as possible the original lines, and the hearth be surrounded with water-cooled plates. The double bell was also found to possess no special advantage, and was abandoned. These changes were introduced in the furnace next erected at these works. But, before leaving this furnace, I wish to emphasize the bearing that the practice of rapid driving, begun on furnace "A," and further developed on this one, had on the general practice of this country. The large outputs obtained from this furnace by the use of a large volume of air, was a matter of common knowledge; the practice of fast driving soon became the accepted one, and with our national ardour it was prosecuted enthusiastically. In every direction, engines that had been running along for years at a methodical gait, were oiled up and started off at a livelier pace; new boilers were added; the old iron hot-blast stoves, not supplying sufficient heat, were torn down and replaced by the more efficient firebrick stoves.

At many works rapid driving degenerated into excessive driving. True, the outputs increased; so also did the consumption of fuel, and that at a surprising rate, until it was thought well nigh impossible to produce a ton of iron with 2,600 lbs. of coke.

1498 Mr. E. C. Potter of Chicago, sounded the note of warning in 1885, and great credit is due to him for demonstrating that large outputs and low fuel consumption are compatible. Since then a marked change in our practice has taken place, and the volume of air blown has been greatly diminished.

Although the practice of rapid driving has been much decried, yet in many ways it has resulted beneficially. It has brought in an equipment of hot-blast stoves, boilers, engines, &c., sufficient to accomplish a large amount of work without a constant strain on every part—a condition very rare prior to 1880; and it has also developed a construction of the furnace stack, by which larger outputs from a single lining can be obtained with less irregularity in the working.

In Fig. 4 is shown a furnace of different construction from either of the preceding, it being my purpose to present successive types of construction rather than changes in the same furnace. We find this furnace constructed with special regard to the better protection of the brick-work of hearth and bosh. The general dimensions are as follows:—Height, 80 feet; diameter of bosh, 23 feet; diameter of hearth, 11 feet 6 inches; stock line, 17 feet; bell, 11 feet; cubical capacity, 21,487 feet. The bosh is placed at about the centre of the stack, making very steep walls. The hearth is also made wider by 6 inches than in the furnace previously described. The hearth walls are surrounded by cast-iron plates with a coil inside for the circulation of water. Around the bottom of these plates is a gutter, through which waste water from the cooling plates flowed, affording better protection to the bottom of the hearth. Above this row of plates, at the tuyere breasts, is another circle of cooling plates, partially inserted in the brick-work. The walls of the bosh are encased in a jacket of wrought iron, $\frac{1}{2}$ inch in thickness. This jacket is bolted on to the mantle. The bosh walls inside the jacket

1499 were made but $22\frac{1}{2}$ inches thick, so that the cooling effect of the air currents on the jacket would prevent any very rapid wear of the brick-work.

It is a fact well known in our practice that the best records are obtained within the first year of the blast, as the walls are not then affected to any great extent by wear. With the better protection afforded by more recent construction, this difference has not been so marked. This furnace was put in blast in 1882, and, in the second month, made the large yield of 6,045 tons, on a coke consumption of 2,617 lbs. In the first twelve full months the output was 65,947 tons, on an average of 2,570 lbs. of coke per ton of iron, thus exceeding by over 11,000 tons, the best output that had previously been obtained in the same time from any furnace at these works, and with a much smaller consumption of fuel. The record for the best month during this period was 6,131 tons, on a coke consumption of 2,837 lbs. per ton of iron. The amount of air blown

was 27,000 cubic feet per minute, which was heated to an average temperature of 1,000 degrees. The pressure of blast at the tuyeres varied between 9 and 10 lbs. After a blast of seventeen months' duration this furnace was blown out, having made a total output of 90,317 tons, on an average coke consumption of 2,613 lbs. per ton of iron.

For what reason this furnace was blown out I do not know, since the consumption of fuel, even in the last two months of the run, did not increase more than 100 lbs. above the average. The furnace records afford no explanation of the cause. As a matter of fact, the results were much better than any obtained for a number of years afterwards. They serve, also, to show how very materially a slight protection afforded to the furnace walls affects the output and the consumption of fuel.

As illustrating the effects of an excessive volume of air, I will mention a furnace put in blast two years later—of practically the same dimensions and protected to the same extent, but blown with 33,000 cubic feet of air per minute—which made an average output of 5,000 tons per month, on a coke consumption of 3,000 lbs. per ton of iron. This is the largest amount of air that I know to have been forced into any furnace. The fuel consumption is what might have been expected, as the furnace was driven at such a rapid rate that the imperfect reduction of the ores in its cooler parts necessitated the completion at a temperature sufficiently high for the CO_2 to react on the carbon.

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In the next drawing, Fig. 5, is shown a different arrangement for maintaining the bosh walls. The lower part of the hearth is surrounded by cast-iron plates. On the top of these rests a water-cooled corset jacket, fastened together with links, and banded at the upper and lower ends by iron bands, 6 inches wide and 1 inch thick. The wrought-iron bosh jacket is dispensed with; and, in its stead, are two bands of water-cooled plates, covering the greater portion of the brick-work. These are held in place by bands at the top and bottom, and also by being inserted a short distance in the brick-work. The tuyere fittings are unique. The arrangement, as shown in the drawing, consists, first, of a large oval block, made of cast iron, and water cooled. Fitting into this, with sufficient space left for clay-packing, is a large bronze cooler, oval-shaped at the outer end, but with a circular opening at the inner end for the insertion of the tuyeres. This cooler was supported by trunnions resting on the block, by means of which the nose could be either elevated or depressed. The tuyeres were shaped to make a ball-joint connection with the cooler, so that a horizontal delivery of the blast could be obtained with any inclination of the cooler. The adjustment was such that the tuyeres were placed in a staggered position, there being as much as 6 inches between the centre lines of each adjacent tuyere. The reason given for this placing of tuyeres was "to obtain a greater area of contact between the fuel and the air." No such benefit, however, was derived, and the tuyeres were subsequently placed on the same level.

1501 The dimensions of the furnace are shown in the drawing. The cubical capacity was 16,680 feet. In February, 1885, the furnace was "blown in." The volume of blast was rapidly increased until, in the following month, it reached 31,000 cubic feet per minute. The blast entered the furnace through eight tuyeres, 7 inches in diameter, and was heated to a temperature of 1,200 degrees. The pressure at the tuyeres was 8½ lbs. The average monthly output from March to August inclusive was 5,122 tons on a coke consumption of 2,874 lbs. per ton of iron.

As this was the third blast for the same furnace (a companion furnace to that shown in Fig. 3), a comparison with the record made at the same relative time on the first blast will show the effect of different rates of driving on the fuel economy. In the first blast the coke consumption was 2,600 lbs., with a volume of air of 24,000 cubic feet per minute; in this blast it has risen to 2,850 lbs., through an increase in the volume of air of 7,000 cubic feet.

On taking charge of these works in October 1885 I endeavored to reduce the volume of blast in order to diminish the consumption of fuel. The reductions were made slowly until the volume was 28,000 cubic feet per minute. Many attempts were made to reduce it still further, but as each attempt was invariably met by great irregularity in the working of the furnace, further efforts in that direction were abandoned. The volume of blast was therefore maintained steadily at 28,000 cubic feet, and the temperature, which before had been quite variable, was maintained more uniformly. At the same time the cinder, which was quite basic, was made less so.

As a result of these changes the output increased to an average of 6,050 tons per month, on a coke consumption of 2,400 lbs. per ton of iron; but after a three months' trial the furnace was suddenly shut down, with a full working burden, for a period of 21 days, on account of labour troubles. After it had resumed, and the
1502 bad working incident to such a shut-down had been remedied, the furnace made an average monthly output of 5,700 tons; but the consumption of coke had advanced to 2,600 lbs., and continued at that figure till the end of the blast. The furnace was blown out, on account of the upper lining being destroyed, after a blast of twenty-three months. The total output for the blast was 118,000 tons, on a coke consumption of 2,705 lbs. For the first twelve full months the output was 64,998 tons, on a coke consumption of 2,677 lbs. per ton of iron.

In Fig. 6 of the drawings is shown a combination of Figs. 4 and 5, in the construction of cooling jackets. From the top of the corset jacket down, the construction is an exact duplicate of the one just described. Between the corset and wrought-iron jackets a row of water-cooled iron plates is inserted in the brick-work. There were eight sections in the circle, all being connected together, and the water was fed from the high-pressure main. The advantage of a high water pressure on this kind of plate is shown by the fact that not a single one was lost during the entire blast.

The interior shape of this furnace differs very materially from

those previously shown, having been made to conform, as nearly as possible, to a furnace at the South Chicago works, which was then giving excellent results in regard to both output and consumption of fuel. The bell is increased in diameter, and the upper walls are drawn in, making a less diameter at the stock line. The bosh is 22 feet in diameter, the total height 80 feet, the cubical capacity, 18,950 feet. There are eight tuyeres, each five inches in diameter.

This furnace was "blown in" in September 1885, and in one week from starting, the volume of blast was 27,000 cubic feet per minute, *and was at this figure when the furnace came under my management.* Within the next two months I reduced this volume to 22,000 cubic feet, which was heated to a temperature of 1,300 degrees.

1503 The product for October was 6,320 tons, and for November 6,306 tons, on a coke consumption of 2,396 lbs. In December, the output on the decreased volume of blast increased to 6,451 tons, and the consumption of coke had fallen to 2,172 lbs. During the months of January and February, 1886, we were unfortunately compelled to shut down for thirty-three days. In the month of March the output was 6,352 tons, on a coke consumption of 2,105 lbs. For the first twelve full months the output was 74,475 tons, on an average coke consumption of 2,250 lbs. per ton of iron. During the last year that the furnace was in blast, the volume of air was gradually increased to 27,000 cubic feet per minute. The inwalls were much worn, and the grade of iron had become variable; but with the increased volume of air the working became very uniform. In the last eight months of the blast, the consumption of coke had risen to 2,500 lbs. After a blast of twenty-six months, the furnace was blown out, having made a total output of 150,374 tons on an average fuel consumption of 2,342 lbs. per ton of iron. At no time in the blast did the coke consumption reach 2,600 lbs., except in the third month before blowing out. The best output obtained in any single month was 6,730 tons.

While these records were much better than any previously obtained at the same works, it was evident that had the bosh walls been entirely protected with cooling plates, still better results would have been got. When exterior cooling jackets only are used, the preserving of the furnace lines depends wholly upon the carbon coating which is deposited upon the brick-work as the latter wears away; in fact, were it not for this protection, the bricks would last but a very short time indeed. When this coating increases in thickness, the furnace works far more regularly and economically; and in a furnace considerably worn, the thickness of this carbon wall is to a great extent the measure of its economical working. We have prepared bosh walls where only 6 inches of the brick-work re-

1504 mained; but inside was found this coating, 18 to 20 inches thick, firmly set, and far more difficult to penetrate with a drill than the firmest brick-work. But, while the thickness of this coating may be increased at will, yet it can only be done at the expense of fuel; and so unstable is the formation, that the expensive operation of building up—extending over months—may be dis-

sipated in a week or two, by running the furnace on an acid cinder.

In Fig. 7 is shown the same furnace as in Fig. 5, with the bosh entirely protected by cooling plates inserted in the brick-work. A comparison of the two drawings will show the changes in construction. The hearth has been widened to 11 feet diameter. The diameter of bosh is also increased 1 foot, and the stock line is reduced 15 inches. The hearth is protected by water-cooled plates, which, from their slanting position, admit of a greater thickness of brick-work at the bottom. These plates are practically automatic, as under an expansion of the brick-work they slide up. In some cases they have raised as much as 3 inches. In the bosh are four rows of bronze cooling plates, eight plates forming the circle, and each plate having two water-courses. In the two lower rows each plate is fed separately; in the upper rows, two plates are connected together. We have found, from quite a number of tests, that the water circulating through these plates increases 10 degrees in temperature. Cast-iron cooling plates are also placed between the tuyeres, the number of the latter being reduced to seven, 6 inches in diameter. The cubical capacity of the furnace is 17,230 feet.

This furnace was "blown in" in March, 1887, and in April made 5,591 tons, on a coke consumption of 2,105 lbs. In May and June the output was small, a stoppage occurring on account of a shortage in the coke supply. In July the output increased to 6,243 tons, and in September reached 7,064 tons, on a coke consumption of 1,993 lbs. The volume of air blown was 24,000 cubic feet per minute, heated to an average temperature of 1,200 degrees. This furnace continued to do excellent work until the following December, when a stoppage of four and a half months occurred, pending an adjustment of the wage question. In the nine months that the furnace had been in blast previous to this stop—and including the stoppage on account of coke shortage—the fuel consumption did not exceed 2,160 lbs. per ton of iron. In May, operations were again resumed. While the output soon reached the former figures, yet the coke consumption was rarely reduced for any one month—even to the end of the blast—below 2,300 lbs. In the period extending from October, 1888, to January, 1890, the average monthly output was 7,000 tons, on a coke consumption of 2,350 lbs. During this period the volume of air had been increased to 27,000 cubic feet per minute. The temperature of blast was still maintained at 1,200 degrees. The average pressure of blast at the tuyeres was 8 lbs. On account of the brick-work in the bosh being very much worn, the furnace was blown out after a run of 2 years, 7 months and 17 days—exclusive of the time the furnace was banked. The output for the blast was 203,050 tons, on an average coke consumption of 2,342 lbs. per ton of iron. The output for the first twelve full months was 72,554 tons, on a coke consumption of 2,230 lbs. For the second twelve months, during which no stoppage occurred, the output was 83,219 tons. The best output made in any one month was 7,680 tons.

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It will be seen by the preceding description that the results both

in output and economy of fuel have been materially affected by the long stops that the furnace was subjected to. Under a continuous run, much better results would have been got.

The advantages of this system of cooling the bosh were very marked, and although quite a number of plates were lost
1506 from various causes during the blast, yet, when a new one was inserted, the furnace invariably showed an improvement in its working.

In the next drawing, Fig. 8, is seen the same construction of hearth and bosh applied to one of our larger furnaces. In fact, the furnace just described was remodelled after this one; but for the purpose of comparing two consecutive blasts on the latter, I have placed it earlier. This furnace was built in 1885–'86. The total height is 80 feet; the diameter of hearth, 11 feet; the diameter of bosh, 23 feet. The bell is 12 feet in diameter, and the stock line 16 feet. The cubical capacity is 19,800. The construction of hearth and bosh is the same as in the furnace just described. There are seven tuyeres, each 6 inches in diameter.

The furnace was started in October, 1886. The record for the next three months is as follows:

Months.	Tons.	Lbs. coke per ton of iron.
November	6,735	2,128
December	7,494	2,105
January	8,398	1,935

From January to May inclusive, the average monthly output was 8,150 tons, on a coke consumption of 1,980 lbs. The volume of air blown was 27,000 cubic feet per minute, which was heated to an average temperature of 1,200 degrees. The pressure at the tuyeres varied from 9 to 10 lbs., and was generally the latter figure when the outputs were largest. In June, the furnace was banked for eight days on account of scarcity of coke, as previously mentioned. As this furnace had been doing such excellent work, the others were banked first, in order to give this one, if possible, a continuous blast; but the supply of coke failed, and although the stop was comparatively a short one, yet, as a result of it, the coke consumption increased to 2,300 lbs. The monthly output from this time, up to January 1888, was 7,400 tons, when a second stoppage on account of labour troubles occurred. The length of this stop
1507 was sixty-seven days; and, although the product was exceptionally large, even to the end of the blast—reaching in some months to over 8,000 tons—the consumption of coke increased to an average of 2,450 lbs.

It is greatly to be regretted that our work does not show an uninterrupted blast; since our records show, in nearly every case, a decrease in output and an increase in fuel consumption from 150 to 200 lbs. per ton of iron, as a result of each "banking up."

A portion of the upper lining giving way in August 1889, the furnace was blown out. The last full month (July) in blast showed

an output of 6,491 tons. The furnace was in blast—exclusive of the two stoppages I have mentioned—two years, seven months, and ten days, and made in that time 224,795 tons of iron, on an average coke consumption of 2,317 lbs. The output for the first twelve full months was 88,940 tons on 2,150 lbs. of coke. The efficiency of the cooling plates in the bosh walls was very marked in this case. The exterior brick-work was in as good condition as at the beginning of a blast, neither a crack, nor a brick forced out of position showing anywhere. After the stack was cleaned out a careful inspection was made. The bosh walls were found to be in good condition. A measurement at the bosh line showed that the furnace had widened out 18 inches, but with such uniformity that the widest variation shown by the guage did not exceed 2 inches. From the bosh line to top of furnace the wear was very much greater. The furnace was relined without delay, and after a two weeks' drying out was put in blast on September 25, 1889, just seven weeks from the time of blowing out. The construction is the same in every particular, except that the diameter of the bosh is reduced to 22 feet, and the stock line to 15 feet 6 inches. The lining runs straight from bosh to stock line. This change reduced the cubical capacity to 18,200 feet. The same number and size of tuyer-s are used. The volume of air blown is 25,000 cubic feet per minute, a reduction of 1508 2,000 cubic feet from that used in previous blast. Beginning with October, the record of monthly outputs and coke consumption to the present time is as follows:

Months.	Tons.	Lbs. coke per ton of iron.
October, 1889	6,521	2,450
November "	9,097	1,897
December "	10,603	1,756
January, 1890	10,536	1,737
February "	8,954	1,859
March "	9,941	1,845
April "	10,075	1,847
May "	10,035	1,884

The best output for any one week is 2,462 tons. The temperature of blast averages 1,100 degrees, and the pressure 9½ lbs. The temperature of the escaping gases is 340 degrees. An average composition is—

CO, 27.5 per cent., CO_2, 11.7 per cent.
CO, CO_2, 0.42 per cent.

Counting the time the furnace was running in the first blast, and up to the end of May, 1890, in the second blast, including also the time spent in relining, the period covered is three years and five months, and in that time this furnace has made an output of 301,205 tons, a record which is unparalleled. In the month of May, this, together with a companion furnace of precisely the same dimensions, made an output of 20,192 tons, on an average coke consumption of 1,882 lbs. per ton of iron. The ores used are from the Lake Superior

region, and yield through the furnace 62 per cent. of iron. The proportion of limestone carried is 28 per cent. of the ore burden, and about 1,200 lbs. of cinder are made per ton of iron. The average analysis of the cinder is as follows:

Silica.....	33.00 per cent.
Alumina.....	13.00 "

The stone used contained but a very small quantity of mag-
1509 nesia. The silicon used in the iron averages 1.60 per cent., the iron being run into ladles and sent to the converting mill direct. The suitableness of the metal for this "direct process," as we term it, will be appreciated from the fact that under the rigid system of foundry grading—by the fracture—the average percentage of Nos. 1 and 2 grades from all of our furnaces for the first five months of this year was 95 per cent., and the analyses of one hundred ladles, filled consecutively from the furnaces, show an average content of sulphur of 0.023 per cent.

I shall not undertake to say what these furnaces will accomplish on an uninterrupted blast, but I believe the day is not far distant when we shall be able to show a record of 300,000 tons from a furnace in three years, and on a single lining.

In the period covered by the last decade there are three steps in the development of American blast-furnace practice that might be mentioned—first, in 1880, the introduction of rapid driving, with its large outputs and high fuel consumption; second, in 1885, the production of an equally large amount of iron, with a low fuel consumption, by slow driving; and third, in 1890, the production of nearly double that quantity of iron, on a low fuel consumption, through rapid driving.

In the following table I give a summary of the preceding data:

Designation of furnace.	Year in which furnace commenced the blast.	Cubical capacity.	Volume of air per minute.	In first twelve full months.				
				Total output from blast.	Output.	Average daily output.	Average coke consumption.	Capacity for one ton of iron per day.
		Cubic feet.	*Cubic feet.*	*Tons.*	*Tons.*	*Tons.*	*Lbs.*	*Cubic feet.*
Isabella	1876	15,000	.....	117,575	28,000	76	3,000	197
Lucy, Fig. 1	1878	15,400	16,000	92,128	33,552	91	2,850	169
Edgar Thomson, Fig. 2	1880	6,396	15,000	.....	.....	*71	*2,400	90
" " " 3	1880	17,868	30,000	112,060	48,179	132	2,859	135
" " " 4	1882	21,478	27,000	90,317	65,947	180	2,570	119
" " " 5	1885	16,680	†31,000	118,000	64,998	178	2,677	90
" " " 6	1885	18,950	22,000	150,374	74,475	204	2,250	92
" " " 7	1887	17,230	24,000	203,050	‡72,554	198	2,230	87
" " " 8	1886	19,800	27,000	224,795	88,940	244	2,150	81
" " " 8	1889	18,200	25,000	.....	§113,300	310	1,920	59

* Estimated.

† After running nine months the volume of air was reduced to 28,000 cubic feet.

‡ The second twelve full months, by reason of a continuous blast, shows an output of 83,219 tons on 2,396 pounds of coke.

§ Estimated from record made to date.

NOTE.—The actual record for Fig. 8, blast of 1889, shows for the first year in blast 113,526 gross tons on a coke consumption of 1,892 lbs. per ton of iron.

At the invitation of the president,

Sir Lowthian Bell said: If the creation of the Iron and Steel Institute had been followed by no more important results than the opportunities it has afforded to those occupied in a common pursuit, of comparing the results of their individual experience, it has done good work. It has taught us, among other things, that any knowledge we may impart to each other must not be regarded as a mere gift, but rather as an exchange, the value of which cannot be estimated by the sum of the two, but by entirely new factors, requiring the united experience and knowledge possessed by the giver and the receiver.

Speaking from my own experience, this has been amply illustrated in the frequent, and, to myself, the most beneficial relations which I have been fortunate enough to establish with a large number of the leading manufacturers in the United States of America, as well as with numerous other friends in various countries of Europe. Lastly, I am indebted to my connection with this institute for the opportunity of again visiting the United States and seeing once more those gentlemen from whom I have received so much attention, and towards whom I feel myself drawn by ties of the warmest friendship.

It is unnecessary to assure the author of the paper before us how grateful the members of this body must feel for the thoroughness of the work he has performed. Iron manufacturers have now been accustomed for some time to follow, as closely as the nature of the operation permits, the action of the blast furnace, and to study the laws which regulate its action. The results, however, which have been communicated to us this morning may well suggest the idea whether we have, in our previous estimates, not overlooked some of the conditions involved in smelting the ores of iron; for we
1512 have not only to consider the low consumption of fuel mentioned by Mr. Gayley, but the hitherto unparalleled large production of iron from one furnace. Thinking that it might interest others as well as myself, I have examined the figures given us by this gentleman, and have compared them with those of furnaces working under very different conditions, and I hope to be able to show you that it is not necessary to look for any new law to account for what, at first sight, seems little short of the incredible.

For this purpose I will omit for the present all the first examples quoted in the document before us, and go straight to the last, which my friend, Mr. Gayley, has properly reserved for winding up his most interesting communication.

The problem before us is to account, if we can, for a furnace producing about five times as much iron as we have hitherto made in Cleveland from our poorer ore, and about twice as much as has been obtained from our hæmatite furnaces of like dimensions in England. And all this has been performed in the particular case

before us with an expenditure of 16.80 cwts. of coke per ton of iron of a high average quality.

The consumption of coke per ton of iron depends on its quality, or on the more or less perfect manner of its combustion, or on the amount of work it had to perform.

Now, so far as concerns Connellsville coke, which was the coke used in the case before us, there is nothing to be set down to superiority of quality; for instead of containing 5 to 7½ per cent. of ash, like the coke of Durham, it has rarely less than 10 per cent., and sometimes more, of this impurity.

The completeness of combustion of the carbon we have to deal with is, of course, judged by the amount of carbonic acid in the gases. Now, when we compare the heat obtained from each unit of coke, estimated as nearly as I have been able from Mr. Gayley's data, partly because the carbon as carbonic acid is, in relation to that as carbonic oxide, slightly below that which is often
1513 found in the gases from a Cleveland furnace, partly because the temperature of the blast is not quite so high, and partly because the ash is higher in the American than in the English coke, a somewhat larger amount of duty is obtained from the latter. The effect of these is evidenced in the following figures:

One unit of coke afforded of heat:

	Cleveland. Calories.	Lucy furnace. Calories.
Carbon burnt to carbon oxide.....	2,032	1,898
Part of above burnt to carbonic acid.... ..	1,672	1,626
Heat in blast.....	727	617
Totals.....	4,431	4,141

showing a difference of 7½ per cent. in favor of the Cleveland furnace. It may be here remarked that the relation between carbon as carbonic acid to carbon*ic* as carbonic oxide in the Cleveland furnace is as 1 to 2-11 against 1 to 2-35 in the Pittsburgh. On the other hand, the actual quantity of carbon as acid in the former is 5-97 cwts. against 4-80 cwts. in the latter furnace. The generation of carbonic acid being almost entirely due to the oxidation of carbonic oxide by the act of reduction, the difference in quantity at the Pittsburgh furnace is due to the carbonic acid generated being returned to the condition of carbonic oxide, involving thereby a loss of 5,600 units or thereabouts per ton of iron. I believe 5-97 cwts. of carbon as carbonic acid per ton of iron, is about the full quantity capable of being produced by the reduction of the ore.

The furnace with which this Pittsburgh furnace has been compared performed its duty under an entirely different class of circumstances, as may be seen from the two columns of figures which follow:

1514

	Cleveland.	Lucy.
Cubical contents.....	25,500	18,200
Temperature of blast.....	704° C.	593° C.
Coke consumed per ton of iron	19-89 cwt.	16-80 cwt.
Limestone "	11-00 "	9-03 "
Ore "	48-00 "	32-26 "
Weight of blast per ton of iron	87-15 "	71-20 "
Weight of gases "	119-47 "	100-10 "
Tempt. of gases "	250° C.	171° C.
Tons of iron for 1,000 cubic feet space of furnace per week.....	21-57	128-00 avr. 3½ yrs. 2,333
Slag per ton of iron.....	28-00	10-71
Calories produced per ton of iron	88,577	69,569

The difference- in the various factors are met by corresponding variations in the appropriation of heat under the various items. These are set forth in the next two columns, the equivalents in coke being also given :

	Cleveland. Coke.	Pittsburg. Coke.
Reduction of peroxide of iron	33,108= 7.47	33,108= 8.00
" metalloids in pig	4,174= 0.94	2,631= 0.64
Dissociation of carbonic oxide.....	1,440= 0.33	1,460= 0.35
Fusion of pig iron.....	6,609= 1.49	6,600= 1.59
Evaporation of water in coke.....	275= 0.06	83= 0.02
Decomposition of water in blast	2,380= 0.54	2,333= 0.56
Expulsion of carbonic acid of lime..	4,070= 0.92	3,094= 0.75
Reduction of the carbonic acid to CO.	4,224= 0.95	3,488= 0.84
Fusion of slag.....	15,400= 3.48	5,890= 1.42
Carried off in gases	7,166= 1.60	5,013= 1.21
Heat lost by radiation, convection, tuyere, water, &c.....	9,740= 2.21	5,869= 1.42
Totals.....	88,577=19.99	69,569=16.80

A very important source of loss of heat may be involved in that carried away in the escaping gases, and the lessening of this bears directly on the large make of the furnace referred to by Mr. Gayley, and accounts for a large portion of the saving effected by the hot blast. Thus when furnaces of 48 feet in height were blown with cold air, nearly 25 per cent. of the effective heat of the coke—say 9 cwt.—was carried off in this way, but by heating the blast to 485° one-half of this was saved, and by doubling the capacity of the furnace the loss carried away in the gases was reduced to less than 2
1515 cwt. of coke. So far as these Pittsburgh furnaces are concerned, I have since my arrival in New York heard the large

make and the economy of fuel set down to the facility with which the Lake Superior ore was reduced. In my opinion, this is doubtful. In my experiments I instituted a large number of comparative trials of the readiness with which different ores part with their oxygen. Of all, I believe the ore of our Cleveland hills retains its oxygen with the greatest tenacity; but, in spite of this reduction, so far as it is affected in the upper zone, is accomplished during its passage through the first 10 feet of its de-cent in an 80-feet furnace. I have, it will be perceived, limited the amount of reduction effected in these 10 feet of depth, because I think a large portion of oxygen—about 25 per cent. of the whole—is retained until the region of the tuyeres is reached. Into the cause of this, time will not permit me to enter upon the present occasion. One cause of the gases escaping at a high temperature is the undue rapidity with which they pass through the solids during the de-cent of the latter. From this it might be inferred that in the Pittsburgh furnaces, with their rapid driving, there would be a tendency to a great loss from this cause, whereas the contrary is the fact, seeing the gas in a given time is three times as great in them as it is in those of Middlesbrough. Now, if we take account of the difference in the cubic capacity, about four times as much as is passing through a given space in the American furnace as happens in the English. The mode of accounting for this apparent anomaly is the only question left for me to bring under your notice. To do this, we may neglect the chemical action going on in the interior of the furnace, and consider the cooling of the gases as effected by their meeting, during their ascent, the descending current of cooler solids.

Let us suppose a tall vessel filled with fragments of small balls, say of calcined Cleveland ore. A current of hot air is
1516 passed through them, and in time the air will flow out of the top at about the temperature at which it enters, the difference being due to loss through the sides of the vessel. We now commence to withdraw the balls, say at the rate of twenty in a minute, adding a similar number at the top. The escaping current is slightly cooler, which means that a loss of heat at the top is still going on, but the balls withdrawn are still at a high temperature. We increase the rate of withdrawal to 200 per minute, by which the gases fall to atmospheric temperature, but 200 balls being too many for the current of hot air to raise to the desired temperature, we must retard the rate of withdrawal until the desired elevation is obtained. It follows, from this experiment, that there is a given ratio somewhat between 20 and 200 balls per minute which gives the best result.

In an old blast furnace of 6,000 cubic feet, smelting Cleveland ore, 36.7 tons of iron were weekly made per 1,000 cubic feet of capacity; the temperature of the escaping gas was 451° C., the blast being 485° C. The loss in coke was 5 cwts., in the escaping gases. After increasing the capacity to 15,500 cubic feet, the loss from this cause was reduced to 2½ cwt.; but instead of obtaining 36.7 tons of iron per week per 1,000 feet of capacity, we only got about 22 tons;

the heat-intercepting power of our furnace charges being equal to reducing the temperature of the gases to 310° C.

It is quite reasonable, however, to suppose that materials might be introduced at the top with a more powerful heat-intercepting faculty than Cleveland iron. I believe that your compact ore, containing one-half more iron than ours, possesses this property, and in consequence your gases escape at a temperature of 160°, which I estimate represents a loss of only 93 cwt. of coke.

If the rate you are driving at represents the position of equilibrium I am describing, you will lose heat and waste coke either by driving more slowly or more quickly than you are now doing.

1517 In conclusion, as I have partly intimated, I am not in possession of all the data necessary for exact calculation. Substantially I hope my figures will prove correct, but it might be well if Mr. Gayley would himself look over my estimates.

Mr. Edgar S. Cook (the Warwick Iron Company, Pottstown, Pennsylvania,) said, that a few days ago Mr Gayley had sent him a copy of his paper, with the request that he should be prepared to make some remarks. After a careful reading of his paper, he concluded that Mr. Gayley had about exhausted the subject, at least as far as the coke practice was concerned. When a single furnace of 18,000 cubic feet capacity could be made to produce 113,000 gross tons of iron in one year, with an average fuel consumption of 1,920 lbs. of coke per ton of iron, little more remained to be said. In view of the vast improvements within the last ten years—which, by the way, were not all due to improved construction and equipment—he would be a bold prophet indeed to put himself upon record by prophesying that the end had been reached. To the average mind it would appear that the possible advances of the future could not compare with those of the past. Nevertheless, there was plenty of scope for earnest endeavor to bring the average work of the many furnaces up to the high standard shown to be possible by the record of the Edgar-Thomson furnaces, as made public by Mr. Gayley.

It had occurred to him that while Mr. Gayley had so fully treated of the large and splendidly equipped furnaces using coke fuel and burdens of the rich Lake ores, the progress made by the smaller furnaces using anthracite fuel might not be without some interest.

During 1872 the State of Pennsylvania produced 968,453 net tons of anthracite iron, and only 388,011 net tons of coke iron out of a total product for the United States of 2,854,558 tons. The Pennsylvania furnaces for 1880 made 1,237,930 tons of anthracite

1518 and 801,817 tons of coke iron out of a total product of 4,295,414 tons; while in 1889 the furnaces situated in the anthracite district of Pennsylvania were credited with a yield of 1,793,639 tons, and the coke furnaces with 2,371,652 tons, out of a total of 8,516,079 net tons for the whole country. Previous to 1882 little or no coke was used in admixture with anthracite. Since 1883 the use of a certain quantity of coke had become almost universal in the anthracite districts. Many furnaces, while in close proximity to the anthracite fields, used coke fuel exclusively; so

that of the 1,793,639 tons credited to the anthracite districts for 1889, only 344,358 tons were made from anthracite exclusively. It would thus appear that the anthracite-iron industry was a decaying one, soon to disappear from the face of the earth, unless the coal railroads adopted a more liberal policy for the future than had characterized them in the past. Coke fuel cost more per ton in the district referred to than coal. The preference shown to the former as a blast-furnace fuel was due to the greater ease with which the furnace was controlled, and the less risk of costly scaffolds and chills. No one who was not practically acquainted with the subject was likely to appreciate the difference in the actual management of furnaces using coal and coke, respectively. The difficulties attending the former greatly exceeded the latter. Mr. Gayley could no doubt speak feelingly on that subject, and he might be willing to attribute part of his deserved success in coke practice to the severe training obtained in the anthracite part of the business. At the same time, if the anthracite furnace was successfully and economically handled, the profits were greater or the losses smaller than if the more expensive coke was used. The development in furnace practice east of the Allegheny mountains within the last ten years would compare favorably with the advancement made in the West, notwithstanding that the yearly product of any single furnace sank into significance when compared with the vast outputs obtained at Pittsburgh and Chicago.

1519 As the Edgar Thomson furnaces fairly represented the progress in coke practice, the Warwick furnace at Pottstown, Pennsylvania, might illustrate the improvement in the anthracite practice, although it was by no means alone in the work. He assumed the management of that furnace in December, 1877. It had been built and first blown in during 1875, and had run with indifferent success, averaging about 20 tons of iron per day. The furnace was originally 16 feet bosh and 55 feet high. The bosh line was afterwards reduced 6 inches and the height increased 6 inches, the capacity being about 5,500 feet. Previous to 1878 furnaces of this size were making from 150 to 250 tons per week, the latter figure being considered rather exceptional. From $1\frac{3}{4}$ to 2 tons gross of coal per ton of iron was about the average fuel consumption. The Warwick furnace in 1878 produced 17,148 tons of 2,268 lbs., an average of nearly 330 tons per week, using 2,912 lbs. of coal per ton of iron. The ore mixture yielded 45.4 per cent., and the furnace was blown with 8,300 cubic feet of air per minute, heated in iron-pipe stoves to 855° Fahr. For 1879 the product was 19,387½ tons, or about 373 tons per week, with 2,912 lbs. of coal per ton of iron. The ores yielded 44.7 per cent.; 8,300 cubic feet of air per minute was used, heated to 850°. The blast terminated in January, 1880, the furnace having run 107 weeks, and making 37,400 tons of iron. In starting it blew on an old inwall. This gave way directly above the boshes, and the gas penetrated to the red-brick shell, necessitating blowing out. At the time this work was quite a revelation, so far as the use of anthracite fuel was concerned, and was the subject of wide remark, occurring as it did about the same

time that the Lucy furnace was showing the possibilities of coke, and creating a stir in the iron circles, not only of that vicinity, but of the country at large. Comments were numerous, and some, of course, unfavorable. It was stated that no furnace brick-work could stand such overdriving—although the difficulty with anthra-
1520 cite furnaces had always been to drive them hard enough—and that the manager, with youthful ambition, was striving to make a record for himself at the expense of his company. As their president and directors were more than satisfied with the financial results, under the most unfavorable trade conditions hitherto experienced, those criticisms did not cause much discouragement.

To illustrate the other side, he could not do better than quote from a letter of Mr. P. L. Weimer, a gentleman widely and favorably known in blast-furnace and engineering circles, published in the Bulletin of the American Iron and Steel Association. Mr. Weimer wrote: "That the record above given is exceptionally good none will deny, and that it demonstrates the value of anthracite as a furnace fuel is equally obvious; but there are several features especially worthy of consideration." Referring to the year 1879 he continued: "The output, which averaged 372.83 tons per week, is greater than the average of coke furnaces of equal size, using the rich ores from Lake Superior, and will compare, in proportion to size, with any coke furnace; the ores averaged 44.7 per cent., while the lake ores employed by coke furnaces average 60 per cent. of iron. Second. The fuel consumption with ores yielding less than 45 per cent. is noteworthy, 2,912 lbs. per ton of iron. Third. The small amount of air per lb. of fuel, 73.63 cubic feet. Fourth. The moderate heat of blast employed, 850°. Fifth. The apparently excessive amount of stoppages"—(in explanation, he would say that the stoppages were largely due to cleaning boilers, no extra set being built at that time; they stopped two weeks each year for boiler-cleaning). "Sixth. The regularity of the furnace operation, neither the maximum nor minimum weekly output varying from the average more than 12 per cent. Only 6½ per cent. of the iron made was other than No. 2 and 3 mill, but 1 per cent. being mottled and white. Seventh. The variety of ores employed, necessitating corresponding changes in flux."

1521 It would be well to bear in mind that at that period chemistry was but sparingly employed; only a few furnaces, the Warwick among the number, making use of the help afforded by analysis. The furnace was relined, no particular changes being made in the construction, and "blown in" in the latter part of March, 1880. They started off well enough, making about 400 tons per week, but the blast was of short duration. During that year, the adverse critics of the improved practice apparently had the best of the argument. The manager was placed in an embarrsssing position. Though firm in the belief that all would come out right in the end, yet, as "success is the best evidence of success," he could not then offer the convincing proof. In 1875 the furnace was built with bosh walls five feet thick, strengthened by upright wrought-

iron brick-staves. That construction was retained in 1880, as light bosh walls were then unknown, or, if considered at all, were looked upon as a hazardous experiment. With the increased volume of air blown and a lower fuel consumption (he never ran by pressure of blast, but always by volume), the brick-work melted rapidly, forming huge pockets or cavities above the tuyeres. These filled with finely divided ore and coal dirt, and the mass slipping at once into the crucible, chilled the furnace. Had they then been as well informed as to the use of the oil blow-pipe as in later years, and had a device, only used at their furnace, termed the tuyere slagging valve, been known, the mortification of a chilled furnace could have been avoided, although it was not probable that the furnace could have been profitable run. The only way he could account for the previous blast not developing the same trouble was by the fact that, for the first month of the blast, the furnace was excessively grey, making vast quantities of slag. The bosh walls became heavily coated—evenly distributed, fortunately—with a graphite covering. This protected and preserved the brick-work, and kept the boshes in good shape. When the furnace was blown out, 1522 the existence of this coating was plainly evident. It proved to be a blessing in disguise, considering the anxiety and worry caused by the overheated condition of the furnace.

Not to prolong that ancient history to too great a length, in recounting the trials of 1880, he would simply say that the bosh was finally fitted with vertical coils of 1-inch pipe encircling the whole circumference, and extending about 10 feet or so above the tuyeres. These coils were supplied with water, which was kept in constant circulation. The pipes were built in the 5-feet wall. The exterior, being in good condition, was not disturbed. The pipes were placed against the melted brick face, and from 12 inches to 18 inches of new brick protected them from the contents of the furnace. That was the first instance, in their vicinity at least, of a water-cooled bosh, and many were the curious comments made upon their placing the furnace in a spring of water. The furnace was put in blast in December, 1880, and continued in blast 245 weeks, making a total of 101,335½ tons, or an average of 413.6 tons per week. That was an unusual total for an anthracite blast. It might or might not have been reached by larger furnaces. Many difficulties were encountered, but patience and close application overcame them. For a few months in 1881, they used one-eighth coke and seven-eighths anthracite; but as that small percentage of coke only added to the cost without giving any corresponding benefit, it was discontinued. They ran on anthracite exclusively until January, 1882, when they commenced using one-fourth coke and three-fourths coal, which proportion they had continued until the present time. For the entire blast of 245 weeks, the ore mixtures averaged 50 per cent., the fuel per ton of iron 2,912 lbs., and the air per minute as 8,750 cubic feet, heated to 865° Fahr. The best average for three months showed 600 tons of iron weekly, with a fuel consumption of 2,212 lbs. per ton of iron. The furnace was repaired in the autumn of 1885.

New hot-blast stoves were built, four sections of the Durham
1523 pattern—6,240 square feet of heating surface, replacing the two small stoves of only 3,600 square feet of heating surface. The thick bosh walls were dispensed with, 22 inches of brick, strengthened by ½-inch wrought-iron jacket, being adopted instead. The bosh coils, or water-cooled pipes, were retained, being placed between the jacket and the brick-work. The capacity of the furnace remained about 5,500 cubic feet. They commenced to blow in December, 1886, and blew out on May 28, 1889. During the blast of 180 weeks, they made a total of 107,595½ tons of iron, an average of nearly 600 tons per week. The ores for the blast averaged 53 per cent., the fuel 2,665 lbs. per ton of iron, and the air was 11,050 cubic feet per minute, heated to 884°. The largest yearly product was 32,738½ tons, the smallest 30,045 tons. The best month's work was 679 tons of iron per week, made with 2,464 lbs. of fuel per ton of iron, when 56.7 cubic feet of capacity made one ton of iron per day, thus slightly exceeding the driving of the Edgar-Thomson furnaces. For the largest year of the blast, 61.2 cubic feet of capacity made one ton of iron per day, and for the entire blast, including stoppages, &c., the average was 64.4 cubic feet of capacity per ton of iron per day, which would compare favorably with the best coke practice, considering the difference in the ores and the fuel used. As a suggestion relative to the capabilities of anthracite, he would add that for one week of that blast, 702 tons of iron being made, 55 cubic feet of capacity produced one ton of iron per day.

The Warwick furnace, however, made a specialty of mill iron, low silicon and low phosphorus, the silicon running from 0.4 to 0.6 per cent. in grey forge grades; the phosphorus being 0.30 to 0.35 per cent. The mottled and white iron made would not exceed 3 per cent. of the total product of any blast, No. 1 foundry being 7 per cent., and the remaining 90 per cent. being grey forge, open and close grain. Up to June, 1889, no change had been made in the
equipment or the size of the furnace since 1872, except the
1524 enlarged hot-blast stoves and an extra set of boilers in order to avoid stoppages for cleaning, one set being idle all the time. During the summer of 1889 the old furnace stack, brick-banded with iron, was torn down and a new steel shell was erected of 16 feet bosh and 70 feet high, with a crucible 8 feet 9 inches in diameter, the cubic capacity being about 8,400 feet. A large Weimer engine and extra boilers were added to the equipment. They blew in on October 6, 1889, and had been in blast now nearly a year. The product would approximate 40,000 tons, the average fuel consumption to date being 2,464 lbs. per ton of iron; the ore mixture 55 per cent., and the air per minute 14,000 cubic feet, heated to 900°. The largest work for any one month so far averaged 823 tons per week, with 873 tons as the best week. The lowest fuel consumption for five consecutive weeks was 2,268 lbs. per ton of iron. For the first year of the enlarged furnace, 76 cubic feet of the capacity had made one ton of iron per day, the largest week showing 67.4 cubic feet capacity per ton of iron per day, which was somewhat above the average of the smaller stack. Before the blast

was completed they hoped to improve the record. The second year of the blast showed the best results. Whether the same would hold good during this blast, remained to be seen.

Mr. A. Thielen (Ruhrort) said: In offering a few remarks on Mr. Gayley's valuable paper, I would point out the strongly contrasting conditions under which we have to work our blast furnaces in Germany, more particularly in the northern district, along the Lower Rhine. The native ores at our disposal contain about 45 to 48 per cent. of iron. They consist principally of the Dutch bog-ores, of burnt pyrites or Blue Billy, and various refuse from chemical works, which are largely used in the manufacture of basic pig. If we attempted to work our blast furnaces so as to attain a monthly production of 10,000 tons, like the Lucy furnace, we should have to put through them a very much larger quantity of material than
1525 suffices in Pittsburgh. If for the Lucy furnace we assume an output of 10,000 tons of pig iron, derived from 63 per cent. ores, and allow for a limestone addition of 25 per cent. then the entire blast-furnace mixture will amount to 16,000 tons of ore, and about 3,500 tons of limestone, making in all 19,500 tons. In Germany, on the other hand, if we take the average of our ores at 46 or 48 per cent. of iron, the ore burden alone will be 21,500 tons, and to this we must add 33 per cent. of limestone, or 7,000 tons; hence we should be obliged to put 28,500 tons of material through the furnace to get 10,000-tons of product. In view of the poorness of our ores, if we should limit ourselves to the same quantity of material as goes through the Lucy furnace, our output would not exceed 6,200 tons.

But there is another essential difference of conditions which prevents our following the example of the American blast furnace. The native ores which we have to depend on are, as a rule, very fine. More than 25 per cent. of the ore in our blast furnaces is of a much finer size than peas, and sometimes as fine as dust. With this material we should be unable to work our furnace at such a speed as is common to the Lucy furnace. So long as we do not get other ores we are bound to use our low furnaces. At no great distance from our Lower Rhine district there is a great body of oolitic ore, which we hope to be able to use to great advantage when a projected canal is built, or as soon as we can induce the Government to lower its rates on rail freight.

The quantity of coke we require is considerably less than that used in the Lucy furnace. With only 48 per cent. of iron in our ores, as against 63 per cent., in the ores of the Lucy furnace, we do not use more than 17 cwts. of coke per ton of pig, with a temperature of blast at the tuyeres of 850° Celsius.

Another reason for our not being able to follow the American lead is that the managers of our Bessemer converters demand at least 1.8 per cent. of silicon in the pig, whereas American
1526 steel workers are satisfied with 0.6 or 0.7 per cent. In striving to emulate American example in this respect, we encountered insuperable difficulties. Without entering into details, I will only mention that our converters use direct metal, in con-

trast to the usual American plan of using cupola metal, which has a higher initial heat. We have to compensate for the lower temperature by keeping the amount of silicon up to 1.8 per cent. I might add another point; we would not be quite satisfied with the costly luxury of relining our furnaces every three years. Thus far we have managed to keep our furnace linings in for thirteen to seventeen years. At the present time we have several furnaces which are working in their sixteenth or seventeenth year, and they still give satisfactory results.

Mr. E. W. Richards said: This history of the development of blast-furnace practice in and about Pittsburgh is a most interesting one. Mr. Gayley's paper, and Mr. Cook's statement yesterday, show that there has been abundance of experience in blowing-in and blowing-out blast furnaces. What are the objects of, and what are the inducements for, the excessive driving? The paper shows us that the cost of doing so is enormous. Labour is dearer in America than in England, so that as much work must be got out of it as possible. But I believe that the charger at the Cleveland blast furnace handles as many tons of material as flesh and blood can well do, and keep up all the year round. So that if the production of a blast furnace is to be doubled, double the men must be employed. It, therefore, seems difficult to understand how this excessive driving can reduce the cost of labour very much. It is probable that an explanation may be found in the satisfaction felt by the owner in a margin of profit, which is so pleasant to see that he instructs his blast-furnace manager to give him tons of pigs—of course at the lowest possible cost—but to give him tons of pigs. Then there is another reason for this fast driving, which to those engaged
1527 in it has a great fascination, and is a constant stimulus to exertion—a stimulus much indulged in here. I refer to the practice of trying to beat the record. Captain Jones was a man of great ability, industry and energy; and we who knew him well sorrow today that he has passed away from us. I had the pleasure, some nine years ago, of visiting with him the South Chicago works. At that time they had a new and magnificent plant of blast furnaces. Mr. Potter had arranged a most powerful equipment of stoves, blast engines, and several batteries of boilers. Captain Jones wrote home to say, "Those boys at Chicago intend to beat our record." And they did. Then the boys at the Edgar Thomson works made their powerful plant still more powerful, so as to beat the boys at Chicago. And so they went on, until in 1885, Mr. Gayley tells us, they forced in the enormous volume of 31,000 cubic feet of air per minute at a blast pressure of over 9 lbs. per square inch, and so overdid it that they burned 2,677 lbs. of coke per 2,240 lbs. of iron produced, and shortened the short and merry life of the blast furnaces. The members of the institute will inquire when at Chicago, and will be very curious and interested to know, who has the record now—whether Mr. Carnegie or Mr. Potter. If Mr. Carnegie has it, he will probably be content with 100,000 tons of pig iron per furnace per annum. If not, then we shall hear of more water blocks, more firebrick stoves, more blast engines, more batteries of boilers.

But the furnaces themselves will have to be of a very greatly increased capacity to work economically, having boshes at least from 28 to 30 feet diameter.

It will be interesting to make a short comparison of the internal form of the furnaces described in this paper, and to know where and how they differ from the English forms, so as to show what has enabled the American practice to produce what are really astonishing results. We are at once struck by the much larger diameter of the hearth of the American furnace, and it is primarily due to
1528 this enlargement of the hearth that the increased output is obtained. But this would be of no great advantage had not the pressure and volume of the blast been at the same time very largely increased. Look at the forms of the furnaces Nos. 2, 3 and 4, and you will see that they have very steep and narrow boshes, which my experience has led me to regard as extremely bad forms—so bad that a furnace with a steep and narrow bosh of 84 degrees, as on No. 3, could not work well and make a regular quality of iron at what we must now term, I suppose, slow driving. Indeed, such a form necessitates fast driving, so as to keep the materials in motion, and prevent scaffolding. Steep and narrow boshes favour the formation of an arched scaffold much more than a flatter bosh. The latter gives an arch of larger radius, much more difficult to form. This arched scaffold gives great trouble when the slip takes place. No doubt the English bell of from 11 to 12 feet diameter is better and much simpler than the complication shown in figure 3. One is gratified to see that Mr. Gayley has discarded this arrangement. The adoption of the 11-foot bell gives a 2-foot space all around for the material to pass. A diameter of throat of 15 feet is a good proportion for a 22-feet bosh. I am not at all in favour of small boshes. The descent of the material in a cylinder is difficult through close packing, so that the diameter from the throat downward, to the top of the bosh should constantly increase, and so release the material from a too close contact, and permit the free passage of the gases. This arrangement at the same time tends to increase the diameter of the bosh, giving greater capacity to the furnace, and favouring a greater production with less forcing.

Mr. Gayley has recognized this, because I observed yesterday, when he was reading his paper, that he said (at page 18): "From the bosh line to the top of furnace the wear was very much greater." Then a few lines further down he says: "The lining runs straight from bosh to stock line." I advocate more that form, making a
15-foot throat, and tapering down to a very large bosh, so
1529 that the materials unpack themselves and the gases pass readily through. The angle of the bosh should, in my opinion, not exceed 75 degrees, and may with advantage be as low as 70 degrees if the bosh is about 22 feet diameter. The lines of the furnace called No. 8 show a return to the English form, with the exception that the tuyeres are placed higher up. I would suggest that if the two great works before named still purpose continuing to compete for the record, the one which adopts the greater cubical capacity will win. Mr. Potter, of Chicago, has already contributed

so much in bringing about the brilliant results now recorded that this first day of October, 1890, will, in the future, be considered an epoch in blast-furnace practice, and will be pointed to and cited as the goal obtained, after years of thought and labour, by many who have devoted time and vast sums of money to reach it. It would be of great service in this discussion if Mr. Potter would give us the results of his experience, for it must be evident that, being such a distance from supplies of fuel, he would give much attention to economy in that direction. There seems at the present moment to be a lull in the race of the rivals. They seem to have got as much out of 20,000 cubical feet of blast furnace as can be got with economy; and we have before us the fact that a furnace using 60 per cent. of mineral produces 2,000 tons weekly, with the very low consumption of 1,920 lbs. of coke per ton of 2,040 lbs. of pig iron made, which is a result of a highly satisfactory character—one that reflects the very greatest credit on the owners and managers, and one of which they may justly be proud.

There is a very interesting feature arising out of this rapid driving. We know quite well that a blast furnace settles down in the course of a couple of months to a certain rate of driving, which gives a regular quality of iron, as in the case of the furnaces making Cleveland iron, 60 per cent. of which is of No. 3 quality, with a yield of 20 cwt. of iron to 20 cwt. of coke. Now, if that furnace be
1530 driven without increasing the coke, the quality of iron immediately falls off, and you have probably No. 4 forge; and if driven a little faster yet, it falls to white iron. But the American practice of doubling the production, with nothing exceptional in the temperature of the blast, makes a ton of Bessemer iron into considerably less than a ton of coke—a result, I believe never before attained. We must presume that this economy of fuel was an accidental outcome of fast driving. At what point of production was this observed? I have constructed several blast furnaces, some with hearths 10 feet in diameter, and some with 11 feet, and have made Bessemer pig iron for steel-making purposes up to 1,000 tons weekly, without remarking any special economy—indeed, rather the contrary, although the temperature of the blast was maintained at about 1,400 degrees. Is it more desirable, or more economical, to drive a blast furnace at a speed of 2,000 tons per month, the wear and tear and all things considered, than to obtain that production from two furnaces? You must have a certain number of stoves to heat the blast, and a certain number of blast engines in order to give you the fuel required, and you must have the requisite number of boilers to work those engines; so that it is simply a question of the outer shell of the blast furnace that we have to consider.

And so I ask, is it desirable, all things considered, to drive the furnaces at such a rate—the paper showing us that the cost of doing so is enormous? Is the iron, when the furnace is driven rapidly, producing 2,000 tons per week, as uniform in quality as when driven at 1,000 tons? It is my belief that it is, because I find, after increasing from 600 to 1,000 tons per week, the quality is as good in making 1,000 tons as in making 600. And so one might infer that

the quality would be as good when making 2,000 tons as when making 1,000. There are other points in this paper that I feel quite sure some other blast-furnace manager will talk about, and so I will not bring them before you, as I think that I have already sufficiently occupied your time.

1531 Mr. E. C. Potter, Chicago, said he was quite sure his friend Mr. Richards had no intention of precipitating a Kilkenny cat-fight between the Pittsburg boys and the Chicago boys. He wanted to assure him that the rivalry was a most generous one, and that each one of them had gained mutual advantage from their mutual comparisons of work. He wanted to say, though, that they had a record of furnace practice at Chicago, which he thought would compare favourably, perhaps, with the magnificent work of the Edgar-Thomson furnaces. Although the figures were not quite so large, still, in comparison with the size of the furnaces, he thought they would furnish considerable food for reflection as to whether the very large furnaces were the ones with which they might expect to obtain the highest possible economy. This record, he was sorry to say, was not accomplished by the furnaces at South Chicago, but by one of the furnaces at the Union plant of the Illinois Steel Company. The furnace in question was comparatively a small one, containing about 8,800 cubic feet capacity. It had made this year, in a single week 1,414 tons of Bessemer iron, and in a month over 5,800 tons; and this rate of production had been continued for several months, showing that it was not merely a "spurt." The fuel consumption for this month was some 59 lbs. lower than the lowest Mr. Gayley had obtained—namely, 1,680 odd lbs.; he did not remember exactly, but it was in that neighbourhood. Now the question that presented itself to his mind in considering the performance of this furnace, and not only this one, but all of the fifteen furnaces now owned by the Illinois Steel Company, was that they had found that invariably the smaller furnaces showed much the better work in regard to output, in comparison with their cubical contents and with their fuel consumption. The performance of the furnace he had just cited showed a product of nearly 2¼ tons of iron per each 100 cubic feet of capacity per day. Mr. Gayley's furnace, to equal this, must make over 12,000 tons per

1532 month, and he did not think that that was quite possible within the light of their present knowledge.

It seemed to him from these records (and they were borne out by the practice in Chicago and the West) that a moderate-sized furnace—say from 10,000 to 12,000 cubic feet capacity—must be the one from which they might look for the best records, considered economically. He could not say that he had come to this conclusion definitely as yet, as they had now under construction at South Chicago a new plant of furnaces of the largest size—the same dimensions practically as Mr. Gayley's. Those were 85 feet in height and 21 feet bosh, with a cubical capacity of about 18,000 cubic feet. Until they had operated those furnaces and determined just what they could do in comparison with the smaller ones, he must withhold his judgment as to which was the best size of furnace for eco-

nomical work. Of course, in considering this, locality playe
very large part. He thought that in the case of the Edgar-Th
son plant, and its proximity to the coke region, where the f
saving was not so great an item as it was in the West, undoubte
very large furnaces, and very large outputs—reducing thereby
labour cost per ton and the item of general expenses—was the
for that locality; but for the West, and for Chicago in particul
they must save the fuel. That was the paramount feature in th
furnace practice. He had noticed with very much interest
Gayley's experiments on his furnace linings and also Mr. Richar
remarks on the same subject. He must say that he was entirely
harmony with Mr. Richards in his criticisms on the furnace linin
They had done a considerable amount of experimenting in Chica
and it had been entirely in the direction of lowering the bosh.

The furnaces described in his paper* before the institute f
years ago, as some of them might remember, were of t
1533 high, steep-bosh kind. These gave very good results as
the driving, and as to the fuel economy, but the serious fa
they found with them was, that for certainly the first six mont
of their life, they had considerable trouble, as Mr. Richards propl
sied, with the sticking, and hanging, and scaffolding, until the f
nace had cut its own lines; and then, during the first six mont
of the second year they usually got their best work out of it.
overcome this, they lowered the bosh of the furnace from 35 f
above the hearth level, to 26 feet above the hearth level, all t
other dimensions being the same. This flattened the angle of t
bosh from 81° to 72°. This furnace behaved very well in rega
to the scaffolding and hanging; they never had an hour's difficul
on that score. But the furnace absolutely refused to drive, a
consequently they did not get as good fuel results as they did fro
the rapid driving. This, of course, was a fatal feature in the C
cago practice. To overcome such a difficulty, they had this ye
put in blast a furnace on lines modified from those just stated
leaving the bosh height the same, 26 feet, and widening the heart
from 11 to 12 feet, giving them their old bosh angle of 81°. Th
furnace seemed to have accomplished all that they had expecte
and it had been working very smoothly from the day of its goin
in blast, driving with reasonable rapidity, and showing very goo
fuel consumption. These two furnaces were now working side b
side, and the last furnace he had spoken of was making from 100 t
150 tons per week more than the other, so that it seemed to him tha
they had very nearly solved the question of furnace lining for th
material with which they had to work.

Mr. G. J. Snelus, F. R. S., said it was a great advantage to th
English members to have had Mr. Gayley's paper placed in thei
hands before they started on their voyage, for it gave many of then
an opportunity of carefully considering the paper, whic
1534 they certainly could not have done amidst the festivities o
which they had been called upon to partake since they ha

* "On the South Chicago iron and steel works, with details of their cost, &c.,
Journal No. I, 1887, p. 163.

arrived in America. He had made it his duty to study the paper carefully, and he certainly was delighted with it. He could not express his thanks too strongly to the writer of the paper, and to the owners of the works, for the munificent way in which they had laid their results before them. He had endeavored to find out the reason for their wonderful output, and for their economical production of pig iron. The large yield, three times as much as they were getting from furnaces of nearly or quite equal capacity in England, with a saving of 20 per cent. of fuel, was, he ventured to say, a point which Englishmen could not afford to overlook; and if they could find out the reason why these results were obtained, by coming the long journey they had undertaken, he was sure they would be repaid for their trouble.

He had endeavored to make a comparison between the several points in the practice at the Edgar-Thomson furnaces with their own practice in England, and he would take the items one after the other as rapidly as he could. First, with regard to the shape of the furnace. He was very pleased to see that No. 8 furnace, which had given those wonderful results, was a return to the old lines of most of their good English furnaces. Mr. Richards had already called their attention to this, and he could say for himself that if they were to place their West Cumberland lines upon the No. 8 furnace, they would find that they would agree with them in all particulars except that the furnace was smaller. The angle of the bosh was identical—75°. The position of the bosh was identical. The proportion of the hearth to the bosh and to the height of the furnace was about the same. So that, so far as regarded the shape of the furnace, he could not see much to account for the improvement which they had met with.

Then with regard to the fuel, Sir Lowthian Bell had said
1535 that the English fuel was better than they had at these furnaces. He was afraid he could not say quite so much for what they got on the west coast of England, but still it was not much worse. They had a coke there which contained roughly on the average about 10 per cent. of ash, and from ½ to 1 per cent. of sulphur. That was about the average of the coke they got in West Cumberland, and he thought that that was about the average quality of the Connellsville coke. So that they might put fuel on one side as not contributing to these wonderful results in any great degree. Then with regard to the ores, they were told that the ores yielded 62 per cent. of metallic iron. The Cumberland ores did not yield so much as that; they yielded probably 56 per cent. on the average. So that here was one point of advantage which they could not afford to overlook, for not only did the ore contain more iron, but it contained less earthy matter, and that, he took it, was a point of very great importance in producing large quantities of material quickly, because they had so much less slag to get rid of, and therefore they had to use less fuel to get rid of it. With regard to the slag, he found, as far as the composition of the slag was given, that there was little difference between the composition of West Cumberland slag, and that usual in the United States. But, as he

had just said, with regard to the quantity, they were at a disadvantage, having to produce considerably more slag to melt and take away than they had at the Edgar Thomson furnaces; so that this was one point where the latter gained. With regard to the composition of the gas, he found that in the Pittsburgh case it was practically the same as they had in England at most of their furnaces, so that this was no point of advantage. With regard to the temperature of the blast, they were told that it was 1,100° Fahrenheit. Well, they were quite up to that in England—in fact that was about the temperature which they regularly got at West Cumberland, so that in this there was no point of advantage. With regard to the pressure of the blast, however, there was certainly a
1536 very important point of advantage. They were blowing at West Cumberland, and had been for many years, a pressure of blast of 6 lbs. to the inch; but here in America they were told they had from 9 to 10 lbs. That, he took it, was a distinct and very great advantage in getting large outputs.

So far as the volume of the blast was concerned, it was quite evident that a very much larger volume of blast was blown through those furnaces than they were accustomed to deal with in England, and he knew it had been a common idea amongst English ironmasters that by increasing the volume of the blast and driving faster they did not economize fuel. He would come to that point later. Clearly, as regarded large output, their American friends had a decided advantage in the higher pressure of blast, and in the greater volume of blast. Then with regard to the radiation of heat from the furnace, he thought that it was quite clear that they had a decided gain under this head, and he could not help thinking that this was one of the points where the saving in fuel was to be accounted for. It seemed to him quite clear that a furnace which was producing as much iron with one casing as they were producing in England with four must radiate a very much less quantity of heat than they did with the four furnaces, and therefore there was a very distinct gain, and probably more than they had been accustomed to allow. In reference to the composition of the material which was made, they were told, with regard to the iron, that it was made low in silicon—a little over 1¼ per cent. Here again, he believed, there was a distinct advantage. Some years back he had had an opportunity of proving that, because they were then able to get supplies of that wonderful material, Campanil ore, which contained only about 5 per cent. of silica, but which was very porous, and enabled them to drive their furnaces faster, to have less slag and to get iron with less silicon. Some years ago he himself had driven furnaces with 1¼ per cent. of silicon, which they
1537 took direct to the Bessemer works. Unfortunately, the Campanil ore had become very scarce, and in Cumberland they could not afford to continue the use of it for admixture, and they had to fall back upon the local ores, which although purer, were more silicious, so that they generally found that in making a non-silicious iron they got a saving of fuel. He thought that that might reasonably be expected.

Here, then, he thought, was one of the causes for this wonderful saving of fuel—that the Americans were working with pig iron low in silicon. They did not use up the carbon to reduce the silicon, and they probably made an iron which contained really less carbon than the English. This was a point on which unfortunately the hands of Englishmen were somewhat tied, because their engineers, when they went into the works, did like to see No. 1 pig with plenty of graphite in it. If they came across a pig iron which was approaching at all to white, they looked very askance at it, and immediately wondered whether bad steel was not being made. Therefore, to keep up the character of their steel, they had very often to go counter to their own idea of what produced the best economy. With regard to the rapid driving of the furnace, he thought this point was most important, because by rapid driving they saved at all points. But one of the difficulties that they experienced with rapid driving in England was that they got a greater consumption of fuel. He never could account for that; he had always been an advocate of rapid driving, but his difficulty was that he could not drive rapidly; the men would not be driven, the manager would not be driven, and the furnace would not be driven, because they had not got the plant, and could not get it. But he certainly believed that when the Americans had the advantage of being able to drive the furnace rapidly, they must necessarily drive it economically, and he was in favor of the practice which they had put forward. He thought himself that they must have great economy by this rapid driving. As regarded the life of the
1538 furnace, he believed in a short life and a merry one. He found that the saving of, say, 4 cwts. of coke to the ton of iron amounted to about £25,000 a year on this particular furnace; surely that was enough money to reline the furnace two or three times over! But the saving of coke was not the whole thing; he thought there was a saving of wages as well. If, instead of the staff to manage four furnaces they got the same result from the staff for one, he was quite certain that the cost of labor per ton would be lower. Therefore, he entirely agreed with the American practice; and if he had to put up furnaces himself, he would certainly rather put up one furnace to do the work than two, although the two might produce the same output; and he would do it even if the two furnaces could be put up at the cost of the one. After having considered all these points, he yet failed to see that the great advantage realized was due to the plant, the material, or the mode of working. He could not help thinking that this splendid result was mainly due to the wonderful spirit of emulation among the proprietors, the managers and the men; and he, for one, would only be too glad, as an Englishman, if English managers, proprietors and men could get contaminated with the same spirit, and he might add that he should be very pleased to carry the influence away with him.

Mr. Julian Kennedy (Pittsburgh) had had a few thoughts suggested to him by Mr. Gayley's paper. The first one was the great effect produced by very small, or apparently very small, changes in

the lines of the furnace. In their original work, when they started out on this fast driving of furnaces—when the work was not really as good as it was now, but when they tried just as hard to get it so—their fast driving was not altogether due to the desire to drive fast. They very often tried a little slower driving, but found that the furnace would not work at a slower rate of speed, and they were therefore forced to drive as they did. He ascribed a great
1539 deal of this to the difference in the furnace lines compared with what they were now. Those differences were not very large, but still they had a great effect, as they had noticed in Mr. Gayley's paper. He found in the case of one furnace, when he tried to reduce the blast, that he came to a certain point, and then he could go no lower. Then, by making a very trifling change in the top of the furnace, he found he could by degrees reduce his blast 3,000 cubic feet. He thought all through the paper they saw evidences of the great effect of very small changes in the lines. When they first started this modern system of driving, their idea was to use a very wide top, and they carried that to the extreme, to their own detriment. Their theory was that the proportion between bell and stock line should be geometrical, instead of arithmetical. Assuming a 7-foot bell to be correct for a 10½-foot stock line, they assumed a 12-foot bell would be correct for an 18-foot stock line, instead of 15, as would now be the practice. All through he thought that the record showed that the lines of the furnace had a great deal to do with the work. He also thought that Mr. Gayley's blast furnace was probably helped a great deal by his system of blowing. Mr. Gayley was equipped with a very fine set of engines, which were regulated by an automatic governor, that could be set at a certain number of revolutions, and would keep up that number of revolutions whether the blast pressure was 16 lbs. or 6 lbs.; and if they were around the engine-house, they would never know the difference. With regard to the economical side of the question it seemed to him that Mr. Gayley had got his coke now to a place that was undoubtedly very satisfactory, and it was doubtful whether it would ever be brought much lower. The labour, he supposed, was all as low as it could be in small furnaces aggregating the same production. The management in some departments must be less. A certain number of men were dispensed with, and if Mr. Gayley succeeded in getting an average life of 300,000 tons to a lining—
1540 which he had no doubt that he would do if he got a blast which he was not compelled to stop by labour troubles or some other extraneous causes—he did not see why Mr. Gayley's practice should not be as good in every respect as it would be with a multitude of small furnaces aggregating the same production.

Mr. William Whitwell said he rose at the call of the president to say a few practical words on their practice at Thornaby, England. Nothing definite had been said during this discussion as to what was being done at the English works, so far as he had heard, and therefore he thought it might perhaps interest some of their English visitors to know what had been done without much pressure, and with a furnace very similar in lines to the one that had been so

highly approved by the several speakers—No. 8. They were working at Thornaby a furnace 75 feet in height and 18½ to 20 feet in diameter, with a bell of 10 feet 6 inches, and with a hearth of 10 feet, with six tuyeres. They did not use the large tuyeres, so successful in America, because up to the present time they had not found it advantageous to do so. Their tuyeres were about 4½ and occasionally touched 5 inches, when required. Their pressure of blast, on the other hand, did not exceed 5 lbs., as a rule, as the working pressure in the engine-house, which practically at the tuyeres meant about 4¾ lbs. They commenced many years ago with smaller furnaces, never more than 20 feet in diameter, and 60 feet in height. They were the first in the Cleveland district to use the rather larger cubical contents of furnace, and to some extent they were successful; but the additional height in the Cleveland district was the great element of success. It was arrived at perhaps more as an accident than otherwise, more with a desire to obtain additional cubical contents than putting in a new bottom to the furnace, and Mr. Vaughan in that respect deserved the con-
1541 gratulations of their own district, and perhaps of the world, because that was the first occasion when greatly cheapened production was obtained.

But to proceed with the hæmatite furnace. He had told them the dimensions. Their make was approximately from 700 to 800 tons per week. At the present time they were working in the fourth year of the furnace life at about 800 tons; and they were improving, doing better, and they anticipated still further improvement. But their ores were very different from the rich ores that they had heard described so vividly here. He should like to know very much when the author of the paper came to reply, whether he would tell them if the general American practice coincided in any degree with what they had heard described by Mr. Gayley, or whether it was one particular individual furnace, working this particularly excellent ore from Lake Superior, and ores of a similar kind. The ore that they used in Cleveland did not average above 50 to 50¼ per cent. It contained mixtures of various kinds. They generally used seven or eight different kinds from Africa, Elba, and from Spain—north and south: and in mixing the ore they tried to arrive at the quality of pig that their customers required for the time being. They did not work so low in silicon as had been the practice in America, and with such advantage too; but they made a pig for Bessemer purposes which ran from 3 to 3½ per cent., and for the Siemens open-hearth furnaces from 2½ to 3 per cent.; and where customers required it they made it from 1½ to 2. They tried to keep their sulphur down. Their phosphorus generally ran a little below .04, and they sometimes got it down to .0275. Their practice was not as regular as that of people who were working for the Bessemer converter or open-hearth furnace, but they made what their customers required—iron for shipment for the continent of one quality, and iron for local consumption of another. They changed sometimes from one week to another, just as was required; but

still, with all that, they managed to get something like 800 tons.

1542 Now as to their coke, the average consumption would run for the last two years, and was now running at something like 19 cwt. per ton of iron, with this 50 per cent. ore. The limestone that they used was the carboniferous limestone from their own district, and they used 6¾ to 6¼ cwt. In that respect they used very much less than was used in America for the richer ores. He was a good deal inclined to think that they might work more advantageously by keeping their furnaces more open, and getting rid of their sulphur more successfully than they were doing if they were to use more limestone; and that was a hint they had got. The average silica in their ore was about 6¾ to 7 per cent.; and if they got that and worked with that regularly, they got pretty equable results. The ore came in, cargo after cargo, and in any work of that description changes were to be reprehended and avoided. The best ores were undoubtedly the most economical to smelt.

There was just one other point that he should like to mention, and that was as to the ores from the north of the gulf of Bothnia, of which they had used something like 8,000 to 10,000 tons a year. That ore owing to the stoppage of the company, was practically no more available, and the last few cargoes were coming in at the present time. If the company went on to secure a future success for this ore, and if they could only confine themselves to a purely silicate ore, they could have nothing better to work with, as that would approximate very closely to Lake Superior ore. On the other hand, there was a great deal of apatite here and there in it, and this was shown by the rather light color. Veins of phosphate of lime ran through the stones which enabled them to select it with ease; and the inferior ore might be used for ordinary purposes with very great advantage, for it was an excellent ore. In regard to the pressure of the blast he was inclined to think they must suit themselves in their driving, and use what pressure was economical

1543 with each. If they wanted their furnaces to run on shorter time, if they were willing to lose something in the quantity of coke consumed, they might use rather more and drive harder; but if they could get their furnace to drive on a certain burthen, he believed that was one point that they ought to look to. They were apt sometimes to put on pressure and drive their furnaces down. That simply meant lowering the quality and rising in sulphur—two decidedly objectionable features, which they always ought to struggle against. One important point for the meeting to consider was this. They in Cleveland changed their heats when their furnaces got too hot rather than burn their iron. In America they never changed their heats, he believed in the best practice. Again, in Cleveland, they worked by pressure. The Americans worked regularly, he believed, by the revolutions of the engine, and they always kept up the pressure, and did not lessen the production of the furnace to keep up the quality, as they in Cleveland did. In those two respects there was something to be learned. Now, how did the Americans do it? They had an individual engine to each

furnace, as a rule, in the best practice. They had not three or four engines working into the same main, and so contributing the common pressure to the one furnace, but they had an individual furnace and fed it with the food most convenient for it, and if it could take more they gave it. They did not check the pressure as they had an engine to work for each individual furnace. If America could give them the same material, with their beautiful Durham coke, the best of which ran from about 5 to 7 per cent., he believed they could show the Americans different results. But with the material they had, and under existing circumstances, he thought that their growth would have to be gradual. He should be glad to know, as he said before, whether it was these individual furnaces, using half a million or three-quarters of a million tons of the best ore, that worked
1544 the best, or whether those using imported ore from Spain or Africa were getting anything like approximate results.

Now, what was the English practice? Their practice was to make the most money, or, in some circumstances, to make the least loss, because it was not always profitable to make iron in England; and if they could keep a furnace going for a long time without checking it for repairs, they thought it was of advantage. As working now, they expected to make something like 475,000 to 500,000 tons of pig iron from one lining in twelve years. If they did that, they were perfectly willing to reline. They could not reline as they did in America. Everything done in America in the shape of repairs or building seemed to be much more rapidly done than they had any experience of in England. He did not understand it. He heard of the Americans relining a furnace (and drying fourteen days too) in seven weeks. If in England they relined a furnace in three months they thought they had done exceedingly well. How they did it in America, whether their labour was more under command, whether their labour was more energetic, or whether there was competition in the labour, he did not understand; but they had something to learn in that respect. Now they simply put their money in their furnace, and perhaps expected to build two or three furnaces for the same amount that the Americans spent on their one furnace and on plant. The Americans had great provisions in heating power, no doubt, but not so much as was given in the Cleveland district. The American practice was to have three large stoves to one furnace with this large production, and therefore they did not work up, perhaps, to the same heat as in the Cleveland district. These were points, as he said before, for individual practice. They would go and see these furnaces throughout the district with intense interest, and undoubtedly they would get all the information they possibly could, and go home and digest it. He believed that the more they heard, the better they should be able to arrive at a con-
1545 clusion as to what was the best for them to do under existing circumstances, but at present they were speaking off book, and simply from the information they had received from time to time. In looking back over many years, it was interesting to visitors to see the enormous increase in production in America. They congratulated their hosts heartily upon it. They were all striving

for the same results, but he was inclined to think that some of the Americans were going much more rapidly than their visitors. Whether they should ever be competitors with them in the markets of the world depended entirely upon themselves. That was an economic question which he should not allude to further. All he would say was this, that he believed that there was room enough, as the president had said in his admirable address, for all of them; and he desired in conclusion to congratulate the writer of that excellent paper, and to particularly thank those American gentlemen who had elucidated the matter so very clearly.

Mr. Wm. Kent (New York), who illustrated his remarks by plate IX, said he had tried to make a study of Mr. Gayley's paper by the ordinary method of a diagram, which he would pin up so that they could look at it. As he interpreted Mr. Gayley's table of figures on page 19, there were three columns which represented results or effects. They were the "average daily output" of the furnace; the "average coke consumption" of the furnace; and the "capacity" cubic feet of the furnace for one ton of iron production per day. He had plotted the upper three lines on his diagram as the result. The red line on the diagram gave the product of pig iron per day. Beginning with the Isabella furnace in 1876 at 76 tons per day, and rising with the furnace in figure 8 of Mr. Gayley's paper in 1889 to 310 tons per day, they would see that the increased production followed a pretty uniform and steady law of rise. The upper lines in the diagram represented the coke consumption, beginning at 3,000 lbs., and declining somewhat
1546 irregularly to 1,920 lbs. The cubical capacity of the furnace for one ton of iron per day, beginning at 197 cubic feet, decreased very rapidly in that remarkable little Escanaba furnace (the furnace "A" of the Edgar-Thompson works which Mr. Gayley described), down to 90 cubic feet; then going to 135 cubic feet; and then decreasing steadily to 59 cubic feet, the present amount of capacity; and, as Mr. Cook told them yesterday, that low figure had been reduced even in the anthracite regions. Those were the three results. They studied the paper and the table to find the causes or the results; and in the table they had two columns in which they might or might not find the causes: first, the cubical capacity of the furnaces; second, the volume of air blown into the furnace. The lower red line on the diagram represented the cubical capacity, beginning at 15,000 feet (the little furnace, of course, went outside the diagram), and then went down to 6,000 feet. Then it came up again to 17,000 feet, and then ran along very irregularly to the present limit of 18,200 feet. The difference between the fourth furnace and the tenth furnace in the list was nearly 400 cubic feet capacity, showing that the cubical capacity of the furnace was nearly a constant quantity. The volume of air was very irregular.

He would ask any one to study that diagram, and see if they could find any relation between the cubical capacity of the furnaces and the volumes of air pumped into the furnaces, or a ratio between these two quantities, considering those two quantities as causes, and those other three lines as effects. He could find no such relation.

ney said that rapid driving increased production and increased
nomy, then, taking out certain figures, he could show them also
the opposite causes would produce the same results; that rapid
ing produced economy, and that slow driving produced economy;
large capacity gave economy, and that small capacity gave
greater economy, and *vice versa;* and so with every other way
that they could put it. So that the mere question of the
volume of air pumped into the furnace, and of the cubical
acity of the furnace, were not the controlling causes in giving
n low consumption of fuel and high production of pig iron. He
not pretend to say what the cause was. He thought that it was
obscure, and one that had yet to be studied. Mr. Kennedy
touched on one cause—the lines of the furnace. That was a
important matter. He thought they would also find that the
sical and mechanical properties of the ore and of the coke were
important conditions. The distribution of the materials in
furnace, the method of charging, and—what they could not tell
t—the inside of the furnace (because they could not get inside
while working), the character of the materials in the various
s of the furnace, and especially in the zones beginning with the
n; and whether the materials at the proper heat for reduction
e pulverulent, or were decrepitated into powder, or were in
ll pieces, allowing the gas to come up freely through them, or
ther they were agglutinated together in a pasty mass, prevent-
the gas from going through—all these, he thought, had a most
ortant effect on the economy of production, although they were
obscure for them to find out at present.

s Mr. Kennedy had said, there were important indications in
Gayley's paper that a change of lines had much to do with
nomy. There was another thing in the paper which showed
, while a furnace was in blast, or in the condition of a furnace
, with all the methods of driving and everything else the same,
, owing to some temporary stoppage, or to some accident, the
ace suddenly changed its rate of working, and reduced its pro-
ion, and that, too, when there was no other change at all; so
they could not discover until they blew out the furnace what
the matter, and then they found that there had been a slip, or
that something had been going wrong inside of the furnace;
the cause then appearing seemed to be a defect in the furnace
lines, or in the mechanical condition of the mass of material
le the furnace. He would say, for Mr. Whitwell's benefit, in
to the question whether this was an exceptional case that had
presented, that the Lake Superior ores were about one-half of
total ore consumption in the United States, and that all the fur-
s running on Lake Superior ores and Connellsville coke approx-
ted very closely to that practice, wherever they were provided
proper equipment, engines, boilers, and ovens. The Lake
erior ore and Connellsville coke, moreover, while they were a
important factor in the economy of production, and in capacity
roduction, were still not the all-important factors, because they
ld find in Tennessee and in Alabama, on much poorer ores and

much poorer fuel, that remarkably large yields were produced, although not equal to those obtained in that locality.

Mr. J. D. Weeks (Pittsburgh) said Mr. Whitwell had asked the question whether that practice was confined to the Lake Superior ores and to this coke. He regretted exceedingly that he had not with him a report of some practice at the Ivanhoe furnace, in Virginia, which showed, with a small furnace, on the ore giving a low percentage of metallic iron, with the Pocahontas flat-top coke of Virginia, he thought, as good results, all things considered, as were shown in Mr. Gayley's paper. The Ivanhoe furnace was a furnace only 12½ feet in the boshes, and it was some 60 feet high. The ore mixture in the furnace yielded about 47 per cent. One portion of it was Pottsdam ore, and the other portion was limestone ore, with very little lime in it, however. The ores were from limestone measures which had been washed, so that the stock went into the furnace in a washed condition. Considerable water came from the washing in connection with it. The Pocahontas flat-top coke was a coke very low in ash—containing somewhere about 5 per cent.—
and it came from a coal that had but a small amount of vol-
1549 atile matter in it—only some 18 per cent., he thought, before it
was coked. That small furnace, with 12½ feet bosh, had been run for the last six or eight weeks, producing about 68 tons of iron per day, on a fuel consumption, with those ores, of but little over 2,000 lbs. of coke to 2,268 lbs. of iron, and it seemed to him that, with the character of ore that they had there, that was an exceedingly good result. If it was desired, he would have the full details of that practice worked out, and, together with the lines of the furnace, given to the institute.* There was one thing more that he had hardly understood in the discussion. He had noticed that the only comparisons that had been made between the cokes had been chemical. They had compared the Connellsville fuel with the Durham fuel simply by percentages of ash. Now, he thought that he was right in saying, that while the purity of fuel was one thing, the physical characteristicces of coke, within certain limits, at least, were of a great deal more importance than even the chemical constituents. He thought that possibly in some of those physical characteristics the Pocahontas flat-top coke was not quite so good a coke, though lower in ash, than the Connellsville coke. It did not have that coating of graphitic paint on it which seemed to him one of the most important things in connection with the working of blast furnaces with their cokes. It seemed that that coating of graphitic paint that they had seen in that country to be common, did not give them hot-top in their furnaces, and in the absence of that silvery lustre which nothing but a coating of graphitic paint could give— a fire-proof coating—they did not seem to have hot-tops and greater fuel consumption than they ought to have with coke with even a lower percentage of ash than they should have, or at least than they then had, in the cokes which had a higher percentage of ash. He had been hoping that their friend, Sir Lowthian Bell, would tell them

* The details had not come to hand up to the time of going to press.

how it came about that a coke of inferior composition as to ash—that was, with a higher ash—would give better results in a furnace than a coke with a lower ash.

Mr. Lowthian Bell said he would just like to say, in answer to the question which had been addressed to him with regard to the nature of coke, that the chemical composition alone afforded only an imperfect explanation of the value of coke as a fuel in the blast furnace. Upon what the value depended he could not tell them, but he knew, that different kinds of coke were more or less easily acted upon by hot carbonic acid. Now, in the event of that action taking on in the upper part of the furnace (which was the only portion where carbonic acid in any quantity was to be found), the coke there was oxidized by the carbonic acid. The effect of this was that two units of carbon escaped as carbonic oxide, evolving therefrom 4,800 calories instead of the 8,000 generated by the one unit of carbon had it left the furnace as carbonic acid. By this action there ensued a loss of 3,200 units; but this was not all. The second unit of carbon thus gasified in the reducing zone never reached the tuyeres, and for all useful purposes in the furnace was much loss. Now, experimentally he had determined that hard semi-metallic looking coke, generally speaking, was better able to resist the solvent power of carbonic acid in the reducing zone than coke of a softer and more porous character.

Mr. Edward Martin, Dowlais, said he had had some experience in coke-making. Some time ago, when he first took the management at Dowlais, they were making a large quantity of coke in ordinary ovens, and without a very good system of washing. That coke was hard, but fairly bright, and worked with a very bad yield in the furnaces. In fact, it was used with difficulty. The same fuel, thoroughly washed in a Coppée washing machine, and thoroughly coked in Coppée ovens, was now doing work equal to the best coke made in the district; and, though its appearance was not at all of an inviting character, he did not think that much depended upon whether the coke was lustrous or otherwise, provided it was hard, dense, and low in ash.

The president said he thought they would agree that it was difficult to exaggerate the value and importance of the paper which Mr. Gayley had submitted to them. It was a very excellent record of the skill, knowledge and energy with which their American cousins conducted their pig-iron manufacture; therefore, they would concur with him in acknowledging that their warmest thanks were due to Mr. Gayley for his admirable paper, and he would ask them to give expressions to their thanks, and tender them by acclamation.

Mr. Gayley said, in reply, that the interest which had been manifested in the paper that he had presented was a matter of deep gratification to him, and he was sure that the discussion which had taken place would be of much value to all. On account of the extent of the discussion, he would make but a very few remarks. He would first allude to the shape of the furnace. That was a matter which had been brought up in discussion. The furnaces shown in

the drawings represented simply types of furnaces. They had but three furnaces when they first started to make these comparisons; afterwards five, and now they had nine. Their general practice had been to decide on one type of furnace, and then to carry that type throughout the whole line. It has been stated by Mr. Windsor Richards that the future development of American furnaces would probably be in the direction of larger capacities; but their most recent experience at the Edgar-Thomson works had been just the reverse. They found that they got a larger output and a lower fuel economy by narrowing their furnace stacks, as they would see by reference to the last furnace that he mentioned, where the cubical capacity had been reduced from 19,800 cubic feet to 18,200 cubic feet, with a larger output and a decrease in the consumption of coke. The tendency was therefore in the direction of narrow
1552 stacks, and he thoroughly agreed with the idea that had been presented as to the angle of the bosh, as that which he had found in his practice to give the best results was 75°. With regard to the quality of the ores, he did not know that they had any data showing the relative deducibility of the Lake Superior ore and of the Cleveland ores; but that was a matter which they were now taking up, and he hoped at some time in the near future to be able to present results on that point.

There was one point in particular in their practice with regard to ores that he wished to emphasize. They used at the Edgar-Thomson works probably eighteen different kinds of ore, and they had a great vari-ty, as they saw, to select from. Now, in a furnace making regular Bessemer iron, they aimed at selecting from those piles of ore such kinds as they had demonstrated by actual practice to give better results when worked together, and their more recent practice showed that they were getting far better results by discarding the lump ore and using exclusively fine ore. By fine ore he would also include those ores obtained from Lake Superior which had a shaly structure. He would also emphasize the selection of coke. They endeavoured, as far as possible, to get their coke from a mine where the quality was as uniform in appearance as possible, paying no attention to chemical analysis, but selecting the hard and silvery coke, and avoiding as much as possible the softer coke, which, as had been explained by Sir Lowthian Bell, was found to waste away at the top of the furnace. They found the peculiar circumst nces there, that during wet weather, or during days when there was a great deal of moisture in the atmosphere, the quality of coke that they obtained did not give them the same duty in the furnace as that made in cold crispy weather. There was less density, it was very much softer, and it crumbled up to a greater extent. He had also found that where a great variety of coke was used from a great many different mines, they got far poorer results than when they made a selection from one or two. He would conclude
1553 by saying that every point in the details of the management of their blast furnaces was emphasized. There was no point, no matter however insignificant it might appear, but which was treated as if it were a matter of vital importance, and in addition to

they had also derived no little benefit from putting in practice many valuable suggestions obtained through the laborious work of Lowthian Bell, whose investigations had lifted the manufacture of pig iron out of the rut of a rule-of-thumb practice, and placed it on a substantial scientific basis.

Correspondence.

Mr. FRED. W. GORDON (Philadelphia): Mr. Gayley's paper calls attention to the very expensive blunder hitherto made in blowing too much wind into a given size of furnace.

It was quite evident from an analysis of blast-furnace operations that the work we are doing in America is anything but creditable. We were consuming fully 1,000 lbs. of coke more than is necessary for each ton of iron made, and were hammering the linings of our furnaces out in a very short time; and nothing but the very high price of pig iron would stand the drain.

It had long been my pet scheme to gradually reduce the quantity of air, at the same time increasing the burden to the maximum and increasing the limestone, and determining if possible the fuel economy which might be reached consistently with the maximum production of the furnace.

After the success of the Isabella furnace at Pittsburg which was remodeled in 1880, the North Chicago Rolling Mill Company had two furnaces relined under my instructions, the bosh being decreased from 21 to 20 feet, the hearth increased from 7 to 11 feet, the angle of 80° to the boshes substituted for one of 75°. The large bell was made 11 feet for a top of 15 feet 4 inches. There was then no practical difference between the Isabella and the South Chicago furnaces.

The result at South Chicago fully justified my anticipations. It gave us the starting point from which to observe what was the most desirable volume of blast. It appeared that this quantity had a relation to the area of the hearth—the most natural thing to look it upon. As, however there is such a vast difference in the efficiency of blowing engines, the tightness of the conduits from the engine to the furnace, and the amount of carbon consumed directly from the oxygen of the ores rather than by the blast, the actual revolutions of the engine made but a poor measurement at the best, so that the fuel consumption, which seemed to be a better standard of comparison, was adopted.

During the winter of 1885 and 1886 I was employed as engineer at the Joliet steel works, Joliet, Illinois, to remodel their furnaces to obtain a fuel economy of less than 2,000 lbs. of coke to the ton of iron. This was accomplished by relining their 20 x 80 ft. furnaces, making the top 16 feet, and putting in 12-ft. bells. With these improvements, a product of about 260 tons of iron per day was obtained, equal to 61 cubic feet per ton in twenty-four hours. In the following summer the same work was undertaken at the Cleveland Rolling Mill Company's furnace, and 210 tons of iron per day was obtained from a 20 x 75 ft. furnace, on a fuel consump-

tion of less than 2,000 lbs. per ton of iron. This furnace was altered by simply banking down, and changing the diameter of the bell from 10 feet to 12 feet 6 inches, the top being 16 feet 7 inches.

In 1885 a furnace at Steubenville, Ohio, only 14 feet bosh and 58 feet high, with a 10-ft. top, 7-ft. bell, and 8-ft. hearth, was blown in, and about 650 tons per week was obtained on a fuel consumption of a little over 2,000 lbs. per ton.

1555 All these furnaces were operated on practically the same materials as those used by Mr. Gayley, namely lake ores, or their equivalent in foreign ores, and Connellsville coke.

I was very careful in the above and other similar work to employ the maximum of blast, and to very slowly increase it until the maximum seemed to be reached, or where the driving of the furnace seemed to affect the grade of the iron or the fuel consumption.

Even a marked change in the furnace was not considered sufficient cause to abandon our line of action, for having applied a certain quantity of blast to a certain burden, it was continued until its effect was established in the furnace. It often happened that with slight changes apparently great disturbances were produced; but they were only temporary, and it was evident that no information would be obtained, and no permanent good results arrived at, if a policy was not followed in spite of all seeming indications that we were in error.

Summing up the result of these and the other operations, it appeared to me that the best measurement for the quantity of blast was the consumption of 5,000 lbs. of fuel per day per square foot of the sectional area of the hearth.

As these hearths were constructed in very much the same way, having about the same projection and number of tuyeres, it was fair to assume the area for comparison as the area of the brick-work when it was first laid.

Again, at furnace "C" and the "Jupiter" furnace at St. Louis, operated by the Western Steel Company, these furnaces were blown in and the same policy was adopted as in the above instances. In this case we had Pilot Knob ore, containing an average of 23 per cent. of silica, of which two-thirds was used, the balance being Iron Mountain washed, a very good and very pure ore, and South-west, also a fine ore, and working freely in the furnace, the mixture containing from 18 to 19 per cent. of silica. This was smelted

1556 partly with Illinois coal in its raw state (as high as one-third by weight was used), and partly with Connelsville, Pocahontas, New River, and Walston cokes. No regular supply of fuel could be had on account of the disturbed condition of the labour market, and the incapacity of the railroads. Those familiar with the fuels named will note the great variety of their structure and composition, and when we smelted this highly silicious mixture with these fuels, we were undertaking no small problem. Yet the result was satisfactory, seeing that, from an 18-foot furnace, 75 feet high, we produced 140 tons of No. 1 Bessemer iron per day on a fuel consumption of 2,100 lbs.—that is, when raw coal was used, estimating a pound of coke as equal to two pounds of coal.

The next experience of importance which I may recite was ob-
ined at the blowing in of the first furnace at Ensley, Alabama.
his plant has four furnaces, 20 x 80 feet, hearth 11 feet, top 16
et, with a 12-ft. bell; angle of bosh 80°. I gave a detailed ac-
unt of the blowing in of this furnace in volume XVII of the
Proceedings of the American Institute of Mining Engineers."
he ores contained about 46 per cent. of metallic iron, and the coke
nsumption per ton of iron was 2,240 lbs., with a product of 165
ns per day.

Adding the fuel consumption of these several furnaces, together,
th a number of others too tedious to mention, wherein quite a
riety of material was used, the average was 4,247 lbs. per foot of
ctional area of the hearth per twenty-four hours, the extremes
ing 5,200 and 3,440 lbs.

If the text of Mr. Gayley's paper is correct in stating that a 22-ft.
rnace had an 11-ft. hearth, the coke consumption in his case
nounted to about 6,000 pounds per square foot, or nearly 50 per
nt. more than the above average.

No absolute rule can, of course, be adopted in this, any more than
other furnace practice, though I believe that something near the
average might be arrived at by comparisons of a great range
57 of furnaces, when doing their very best work, and it seems
that it is an important question to consider.

The old question of the temperature of the blast has been very
haustively discussed from time to time. The inference seems
tural that if heat carried in by the blast may be substituted for
at produced in the furnace by fuel combustion up to a certain
mperature of blast for a given ore and fuel, each calorie then in-
duced may supplant that amount of fuel which would have
nerated a like quantity of heat in the said furnace.

The ratio of CO to CO_2 in the temperature of the escaping gases
ing the measure of the heat utilization in the furnace, the blast
mperature (while within practical limits) should be increased until
e percentage of CO_2 falls, or the temperature of the gases unduly
creases.

In my practice I have invariably employed the highest blast
mperature that could be maintained, with a reasonable degree of
gularity, and have never found a case where a reduction in the
st temperature would improve the condition of the escaping gases,
her in composition or temperature. Hence I believe the limit has
been reached for the highest fuel economy.

If as desirable a gas can be obtained in cold blast-furnace practice
when the blast is heated to 1,600° Fahr., and *vice versa*, I think
e proposition is proved; but I have found that the lower the blast
mperature, the more difficult it was to get, and where atmospheric
mperatures are employed, only selected ores, flux, and fuel will
e the result, and that selection had a very narrow range indeed.

A small charcoal furnace was remodelled to my drawings as fol-
ws: Total height, 60 feet; diameter of bosh, 7 feet 7 inches;
arth, 3 feet; top, 5 feet; bell, 3 feet, the furnace being blown with
e tuyere. There was no semblance of a hot blast. The ore used

was a mixture of brown hæmetite, averaging 50 per cent.; limestone, as pure $CoCo_2$ as could be obtained; the fuel was char-
1558 coal, with an average of 85 per cent. of carbon (the balance being mainly moisture). A burden of 1,120 lbs. of this ore was carried on 600 lbs. of charcoal, and a product of 15 tons of Nos. 1 and 2 car-wheel iron per day was obtained.

This result will come out as well as any furnace-work I have any record of, either cold or hot blast, for the utilization of the fuel in the furnace. It was, however, only after repeated trials with many mixtures that such a result was reached. A slight increase of alumina or magnesia, or a change of the character of the ores, though giving almost the same flux, reduced the grade. The furnace could not be safely kept on this burden while hot-blast furnaces have been kept steadily on a burden equal to this, plus that which could be carried by the blast heat.

Again, though it is heresy to say it, the heat of the blast has no influence on the percentage of silicon. Given an ore mixture, a limestone, and a fuel, and the lowest percentage of silicon that can be reached with cold blast may be slightly reduced by increasing the blast temperature. Not that the blast temperature has any other effect than that the amount of silica present due to the ash of the fuel is reduced by the reduction of the fuel itself to the iron made. It is, however, easier to increase the silicon when using highly heated blast, and only good burdening will keep it under control.

My experience at St. Louis, when smelting the mixture above referred to, carrying 18 per cent. of silica, with New River and Pocahontas coke, containing about 5 per cent. of ash, and only 2 to 2½ per cent. of silica—having the slag as high as 40 per cent. in silica—was that the silicon would average too low through the grain of the pig, and the sulphur was all that could be desired in a No. 1 Bessemer iron. The high price of coke (some $6.50 per net ton) made the fuel economy so important a consideration, that iron higher in silicon was purchased, while the heavy burdening with the low silicon was continued. Mr. Charles Stewart, general
1559 manager, informed me that when the Connellsville coke was obtained in quantity, the silicon was much more at his command. There a small percentage of silica in the fuel governed the silicon in the iron, while the effect of heating the blast some 1,600° Fahr. could be neutralised by an increase of burden.

My own and Mr. Edward Dowd's experience at Sheffield, Alabama, with Pocahontas coke has convinced both of us that with pure fuel, ores high in silica can be used to produce No. 1 iron with very low average silicon, no matter how high the temperature of the blast may be.

With these facts, and this sort of reasoning, I fancy that had Mr. Gayley employed 1,500° Fahr. instead of 1,100°, he might have exceeded his excellent record.

Mr. John Birkinbine (Philadelphia) remarks that the data presented by Mr. Gayley in his paper, and that brought out in the discussion, illustrated the practice of some of the more important American blast-furnace plants, and while the figures given had as-

med proportions which, as mentioned by Sir Lowthian Bell, were rprising, they were not relatively more so than some of the results tained in the smaller furnaces of the United States. A record ade of the average work of the American blast furnaces would fall r below that given by Mr. Gayley; but if the figures he offered re compared according to the cubical capacity of the furnace, and due allowance was made for ores, fuel, temperature of blast, &c., me of the smaller furnaces would be found as well up in the race. ie demands made upon American blast-furnace managers had en such as to develop characteristics in some who were operating ose blast furnaces that had done more than anything else to bring em prominently to the head of the profession, and, in discussing r. Gayley's paper, Mr. Birkinbine would confine his remarks to o features, namely:—

1st. The remarkable output and low fuel consumption obtained some of the smaller blast furnaces, particularly in those using charcoal as fuel.

60 2nd. The personal factor of management, which, after all, is the true secret of the remarkable and unusual records which d been presented in Mr. Gayley's paper and in the discussion.

Few American blast furnaces, using charcoal as fuel, reached the mensions of the smaller furnaces using coke. The largest charcoal rnace in the United States had a diameter of bosh of 14 feet and eight of 60 feet; the next in size had a bosh 12 feet in diameter, d a height of 65 feet; an average size of the blast furnaces now tive which used charcoal as fuel would show a bosh diameter of and 11 feet and a height of 50 feet. Iron pipe stoves, as a rule, re in use, but firebrick stoves were connected with four or five nts, and a few furnaces were still operated with cold blast.

Without burdening the discussion with data obtained from numer- s blast furnaces, the results secured at two of the blast furnaces ing charcoal as fuel were presented.

The first of these was the record of nine years' operation of the ring Lake furnace, located on the eastern peninsula of Michigan. is furnace had a stack 46 feet high, with a bosh 10 feet 6 inches diameter, having a crucible 5 feet in diameter, and a bell of 5 feet. was blown by a vertical engine, with air cylinder 5 feet in diam- r, and a 4-foot stroke. The blast was heated in iron pipe stoves 850° Fahr., and entered the furnace through four 3½-inch tuyeres. e average yield of the ore mixture, which was chiefly soft hæma- s from the Lake Superior region, was from 58 to 61 per cent. is furnace was first started on March 4, 1880, and up to Septem- r, 1889, a total period of 3,471 days, the furnace had operated 3,205 ys, or about 8⅞ years. Complete data subsequent to September, 89, was not now at hand, but the following table would illustrate duration of the different campaigns, and the results obtained in h.

The iron was weighed from the furnace at 2,260 lbs. to 61 the ton. The charcoal was charged by measure, 2,748 cubic inches to the bushel, the weight averaging 20 lbs. To this

table, as presented by Mr. J. C. Ford (the manager), Mr. Birkinbine had added the calculated weight of charcoal per ton of iron.

	Total days.	Stops.	Net days.	Gross tons of pig iron made.	Tons of pig iron per day.	Bushels of charcoal per ton of iron.	Weight of charcoal per tons of iron.
							Pounds.
1st blast	677	7	670	29,040	43	94	1,880
2nd blast	799	7	792	33,124	42	95	1,900
3rd blast	331	11	320	15,279	48	89	1,780
4th blast	510	14	496	26,868	54	88	1,760
5th blast	586	10	576	29,237	51	92	1,840
6th blast	361	10	351	20,451	58	95	1,900
Totals and averages	3,264	59	3,205	153,999	48	92.4	1,844

This table showed that there was an average product of 48 gross tons per day, and a total consumption of 92.4 bushels or 1,848 lbs. of charcoal per ton of iron made. In the first year of its operation, this furnace made, for one week, a ton of pig iron on 1,715 lbs. of charcoal.

The second example was the Hinkle furnace, located at Ashland, Wisconsin, on Lake Superior, using entirely soft red hæmatite from the Gogebic range. The furnace is 60 feet high, with a bosh diameter of 12 feet, and was equipped with two firebrick stoves 18 x 60 feet, and a vertical engine with a 6-foot blowing cylinder and 4-ft. stroke. Mr. Morris R. Hunt (manager of the company) had supplied the following information:

"The furnace was first blown in April 4, 1888, and blown out June 30, 1888. During this time it made 3,261 gross tons of pig iron. The actual days working were 73, and average daily output of 44.67 gross tons of pig iron.

"It was again blown in August 21, 1888, and blown out August 1, 1889. During this period, under Mr. Hunt's management, 1562 it made 26,137 gross tons of pig iron. The actual days of work numbered 316, and the average daily make was 82.71 gross tons of pig iron.

"The furnace was again blown in September 9, 1889, and in the interval of 14½ months just passed presented the following remarkable record:

Total length of campaign	443 days.
Actual running time	382 days.
Total output of blast	41,600 gross tons.
An average of	109 tons per day actual running time.
The yield of ore was	55 per cent. iron.

he average consumption of charcoal per ton of iron.. ..... 1,815 lbs.
he average consumption of limestone per ton of iron..... 177 lbs.
he cubic capacity of the furnace is... ... 3,500 cubic feet.

500 cubic feet of air per minute was blown into it through six inch tuyeres at a pressure of about 5½ lbs., and a temperature of bout 1,300°. The best week's work was made during the visit of e Institute to the United States, when 1,009 tons of iron were pro-uced on an average fuel consumption of 1,806 lbs. of charcoal. uring that week the ores yielded 56.4 per cent. of iron, and 9,300 bic feet of air at a temperature of 1,300 was blown into the fur-ace. The limestone burden was 4½ per cent. of the ore burden, he composition of the cinder at the Ashland furnace is reported as arying from 46 to 51 per cent. of silica, and 11 to 15 per cent. of lumina."

In each of the different classes of blast furnaces—that was, in the rnaces using anthracite coal, coke, or charcoal—and in most of the on-producing districts, a few furnace plants had attained promi-ence by reason of large outputs, or a low fuel consumption, or both, nd some of the works using lean ores, or ores difficult to smelt, ere doing almost as remarkable work as some of the others whose aterials or facilities gave them advantages. It was not always at the finest-equipped plants achieved the best results; on the ntrary, quite a number of the blast-furnace managers who had tained enviable reputations had furnaces with but moderate equip-ments, and the credit of unusual outputs or low fuel consump-563 tion seldom rested with the plants, which had, as legacies, descended from father to son. A majority of the blast fur-aces which had brought credit to the pig-iron industry of the nited States were managed by well-educated men, who graduated om the office, the laboratory, or from some other department con-ected with the industry. A visit to the plants which had been ost successful indicated a thoroughness of management, and a care to detail, which was impressive, and convinced a stranger at once at there were good reasons for the results obtained. The factor of ersonal management as affecting the output and returns of a blast rnace was too often overlooked, and even when credit was given r it, the full importance of such management was not appreciated. Constant vigilance, strict attention to details, and a thorough miliarity with all the various features of the plant were necessary, nd, in addition, acquaintance with the chemical and physical char-teristics of the materials for the furnace, as well as of the compo-tion, structure, and suitableness of the product for the markets ccessible, were prerequisites of good furnace management. But the nenomenal results which had been obtained were largely traceable a confidence born of a realization of competence to handle the ant, together with prompt and aggressive action in emergencies. Mr. W. Hawdon (Middlesbrough) writes that in Mr. Gayley's aper the temperature of the blast is stated to be 1,200°, which

would appear to many, in England, at any rate, to be low. But as Messrs. Siemens had within the last few years corrected their water pyrometer (which was generally taken as the standard in such matters) in such a manner that what formerly was shown at 1,500° was now 1,250° or thereabout, this 1,200° was probably about the same temperature as was the practice at most of the best English works.

In manufacturing pig iron in Great Britain, they tried to
1564 obtain two results, viz., economy of fuel, and, consistently with that, large makes. English practice had been: 1st, economy of fuel; 2nd, production.

American practice had been—1st, large production; 2nd, fuel economy. There seemed to be an economic limit in driving a furnace, which varied for some hitherto unexplained reason with different furnaces. Instance the last furnace on Mr. Gayley's list. It was something beyond any chemical phenomena, and appeared to be due to such a construction of furnace, and such favourable conditions of working that the material was presented at the zone of fusion in a manner and condition that caused rapid fusion to take place. And Mr. Gayley seemed to have hit this off in the furnace which he had last described. In England they had furnaces very much on the same lines, doing excellent work.

Now, the average consumption of coke, leaving out the top item on the list, which appeared to be abnormal, was 2,400 lbs. = 21½ cwt. of coke per ton of iron made.

Compare this with English practice, using Spanish ore of 50 per cent. iron, as against the Lake Superior ore of 63 per cent., used in Pittsburgh. It would take at least 1 to 1½ cwt. more coke to smelt this 50 per cent. ore, or, taking *ing* Mr. Gayley's figures, it would take 21½ x 1 = 22½ cwt. of coke per ton, whilst in England 19 cwt. and even 18 cwt. was pretty general practice.

To make 2,000 tons with one furnace in a week required the same number of blowing engines, boilers, and stoves as would be needed to make it in two furnaces; and therefore the only extra cost in plant would be, in the latter case, the actual furnace stack itself, costing about £5,000, with gallery, &c.

By using the two furnaces to make 2,000 tons per week, and saving 2s. 6d. per ton, they should save this amount in twenty-four weeks. He allowed the 1½d. extra for additional labour that would be required in the front of the furnace. There would also be a considerable saving in relining, which, with rapid driving, was
1565 a serious item. Therefore, judging by these figures, it had clearly paid English makers to use two furnaces rather than one.

Mr. John M. Hartman calls attention to the work of a furnace belonging to the Franklin Iron Manufacturing Company of New York, working on fossiliferous hæmatite of the Clinton group, anthracite coal from Scranton, Pennsylvania, and Connellsville coke. The furnace, which has a cubical capacity of 6,731 feet, and 10 tuyeres, 4½ inches diameter, 6 feet up from the hearth, has a water-cooled bosh and tuyere and crucible jackets. The hearth is 10 feet

6 inches diameter, and there is one cinder notch 4 feet up from the hearth. The furnace is worked with two blowing engines and three firebrick stoves. One week's work in 1886 showed the following results:

Fuel, one-third coke, per ton of pig	2,538 lbs.
Ore per ton of pig	5,091 "
Limestone per ton of pig	1,426 "
Blast per minute	13,514 cubic feet
Temperature of blast	1,100° F.
Temperature of escaping gas	210° F.
Iron produced—No. 1, 342 tons; No. 2, 260 tons; No. 3, 12 tons	614 tons.
Cinder per ton of pig made	2,474 lbs.
Yield of ore	44 per cent.
Ratio of escaping gases by weight $\frac{CO_2}{CO}$=.938 cubic feet of air per minute	2,000 feet.

The furnace for the whole year 1889 gave the following results after relining:

Fuel, one-third anthracite, two-thirds coke	3,091 lbs.
Ore	5,376 "
Limestone	1,485 "
Iron per week	583 tons.
Output—No. 1, 11,002; No. 2, 16,846; No. 3, 2,476.	30,324 "
Average heat of blast	1,250° F.
Maximum heat of blast	1,350° F.
Average air per minute	16,000 cubic feet.
Maximum air per minute	18,100 "
Average pressure	9½ lbs.
Maximum pressure	11 "
Average yield of ore	41 $\frac{6}{16}$ "
Air per minute per 1,000 cubic feet of contents	2,277 cubic feet.
Maximum air per minute per 1,000 cubic feet of contents	2,689 "

1566 Mr. James Gayley writes to say that the question of the comparative reducibility of Cleveland ore and the lake ores of America has often been touched on in comparing English and American blast-furnace practice, and as it has always figured as an uncertain factor in such comparisons, I have had some experiments made which throw light on the subject. The ores selected for the tests are the ones principally used in the mixtures at various works for the production of Bessemer iron. The experiments were conducted by Mr. Grammer in my laboratory, under precisely the same conditions, and with the same apparatus, &c., as are described in Sir Lowthian Bell's "Chemical Phenomena of Iron Smelting;" and, for the purpose of comparing with some definite experiments, it was decided to follow the conditions governing experiments 36, 37, &c., recorded on page 18 of that work. The quantity of CO passed

through the apparatus was 63 litres in 6 hours; the temperature obtained was 780 to 790 degrees Fahr. The results are recorded below:

Ore number	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	Average.
Per ct. Fe in ore	66.0	58.8	62.4	62.6	68.8	61.0	65.5	67.4	62.0	64.6	61.6	62.2	63.9
Per ct. original ore moved	48.0	46.4	41.4	40.2	38.7	31.7	29.5	29.4	23.1	14.7	12.7	10.3	30.5

From the preceding table it will be seen that the average removal of oxygen is 30.5 per cent. Comparing this with the results obtained by Sir Lothian Bell as recorded on page 18, we find—

Exp. 36.—Calcined Cleveland ore, containing 40 per cent. Fe. Original oxygen removed, 37.3 per cent.
Exp. 37.—Lancashire hematite, containing 66.6 per cent. Fe. Original oxygen removed, 35.9 per cent.

which shows that the average lake ore in America is somewhat more refractory than either the Cleveland or the Lancashire ore. The ores above given are all used extensively, and are selected as representing an average mixture at many American blast furnaces.

(Here follow diagrams marked pp. 1567 to 1575, incl.)

1576 United States Circuit Court of Appeals, Third Circuit.

And afterwards, to wit, on the seventeenth day of March, A. D. 1899, this cause being called for argument on the transcript of record from the circuit court of the United States for the western district of Pennsylvania, before the Honorable Marcus W. Acheson and Honorable George M. Dallas, circuit judges, and Honorable Andrew Kirkpatrick, district judge, and being argued by counsel for the respective parties, *and* the court, not being fully advised in the premises, takes further time for the consideration thereof.

And afterwards, to wit, on the twenty-first day of August, A. D. 1899, comes the parties aforesaid, by their counsel aforesaid, and the court, now being fully advised in the premises, renders the following opinion, to wit:

PLATE I.

TO ILLUSTRATE MR. GAYLEY'S PAPER ON "THE DEVELOPMENT OF AMERICAN BLAST FURNACES."

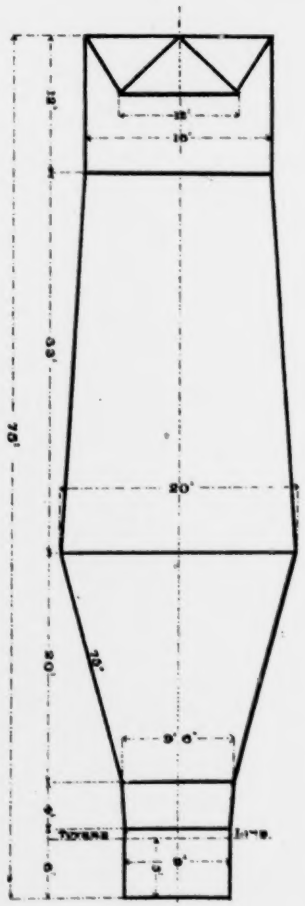

FIG. 1.

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Carnegie Steel Co.
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Cambria Iron Co. } p. 15 by

PLATE II.

TO ILLUSTRATE MR. GAYLEY'S PAPER ON "THE DEVELOPMENT OF AMERICAN BLAST FURNACES."

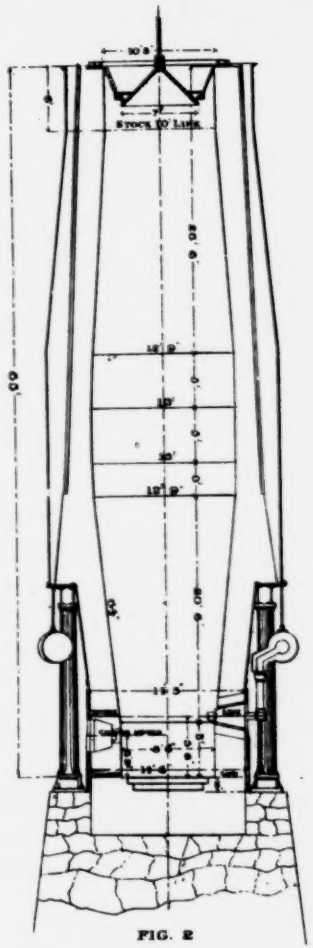

FIG. 2

Cunningham, Hanson & Co. Edinburgh & London.

Carnegie Steel Co. v. Cambria Iron Co. } p. 1568

PLATE III.

TO ILLUSTRATE MR. GAYLEY'S PAPER ON "THE DEVELOPMENT OF AMERICAN BLAST FURNACES."

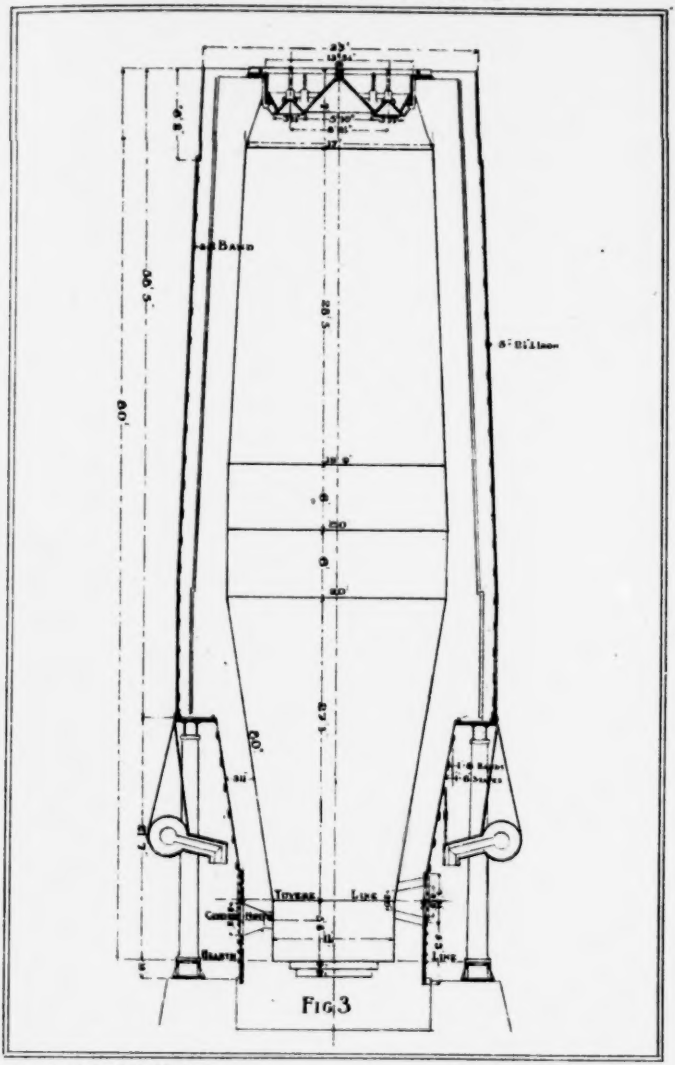

FIG 3

Journal of the Iron & Steel Institute

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Cambria Steel Co
" Cambria Iron Co } p. 1569

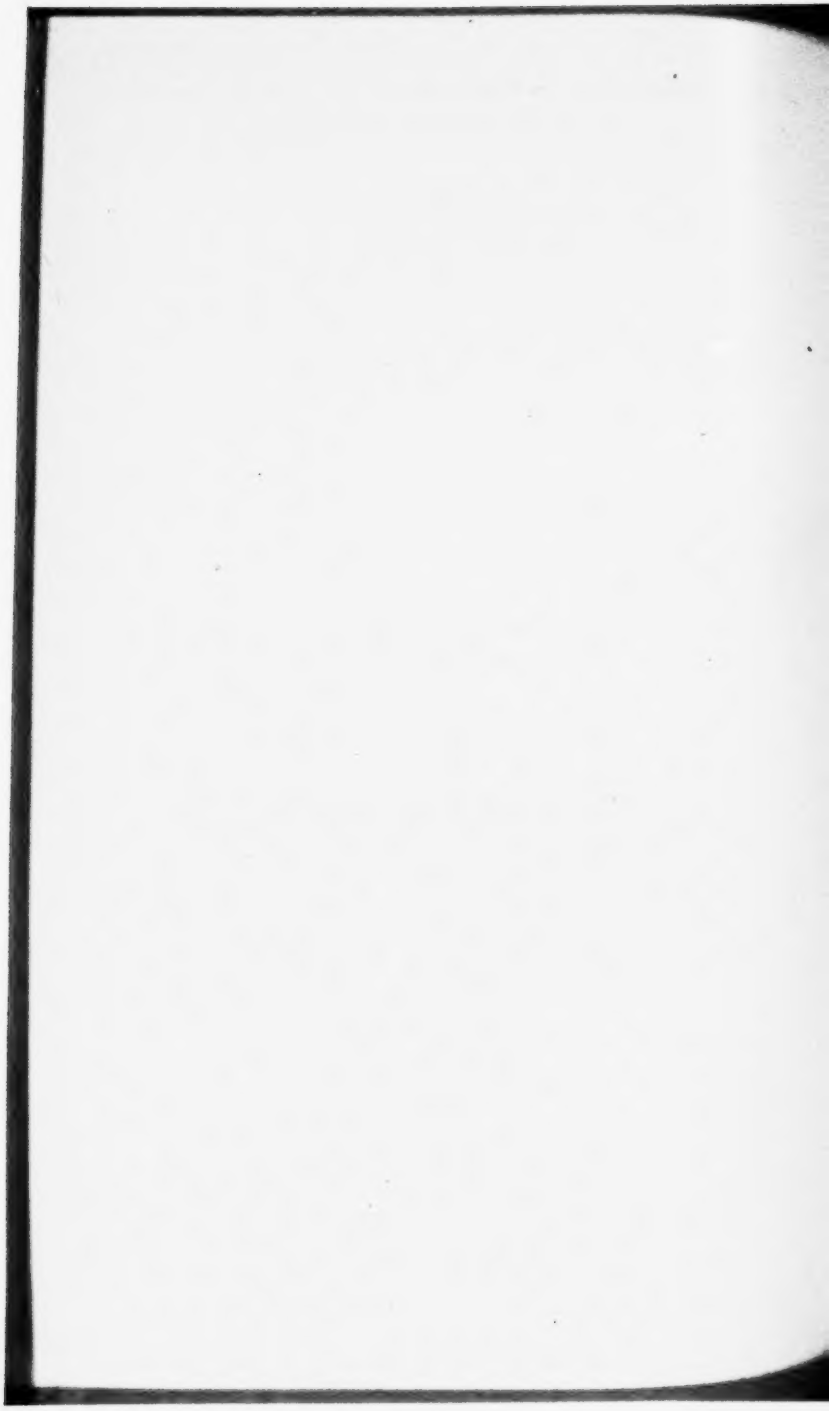

PLATE IV.

TO ILLUSTRATE MR. GAYLEY'S PAPER ON "THE DEVELOPMENT OF AMERICAN BLAST FURNACES."

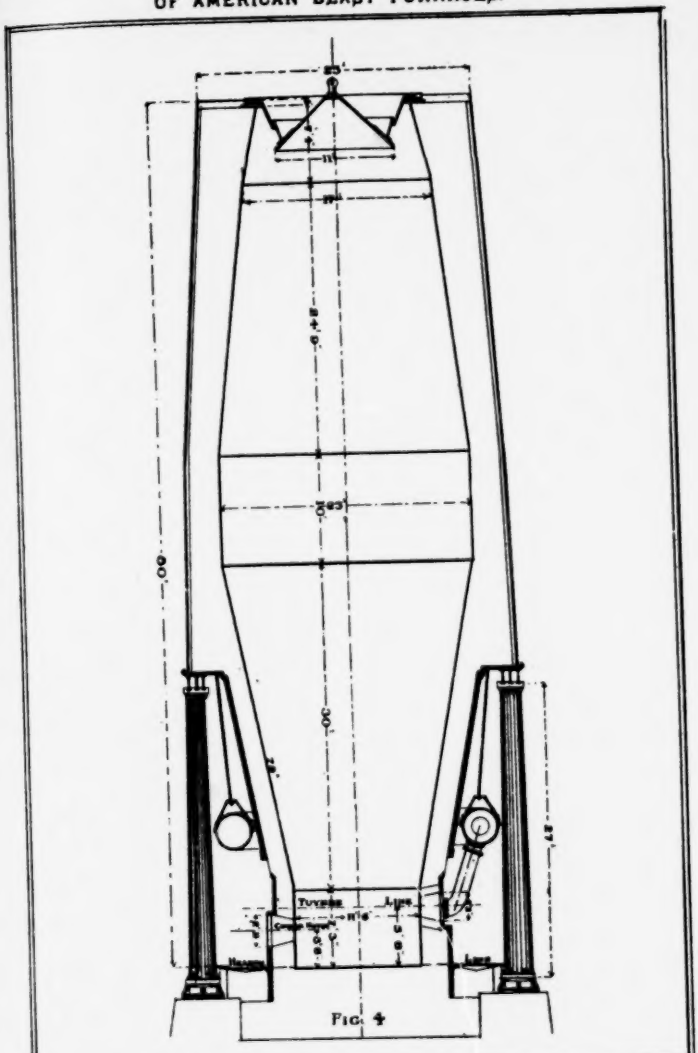

FIG. 4

Journal of the Iron & Steel Institute

Ballantyne, Hanson & Co. Edinburgh & London.

Carnegie Steel Co
Cambria Iron Co. } p. 1570

PLATE V.

TO ILLUSTRATE MR. GAYLEY'S PAPER ON "THE DEVELOPMENT OF AMERICAN BLAST FURNACES."

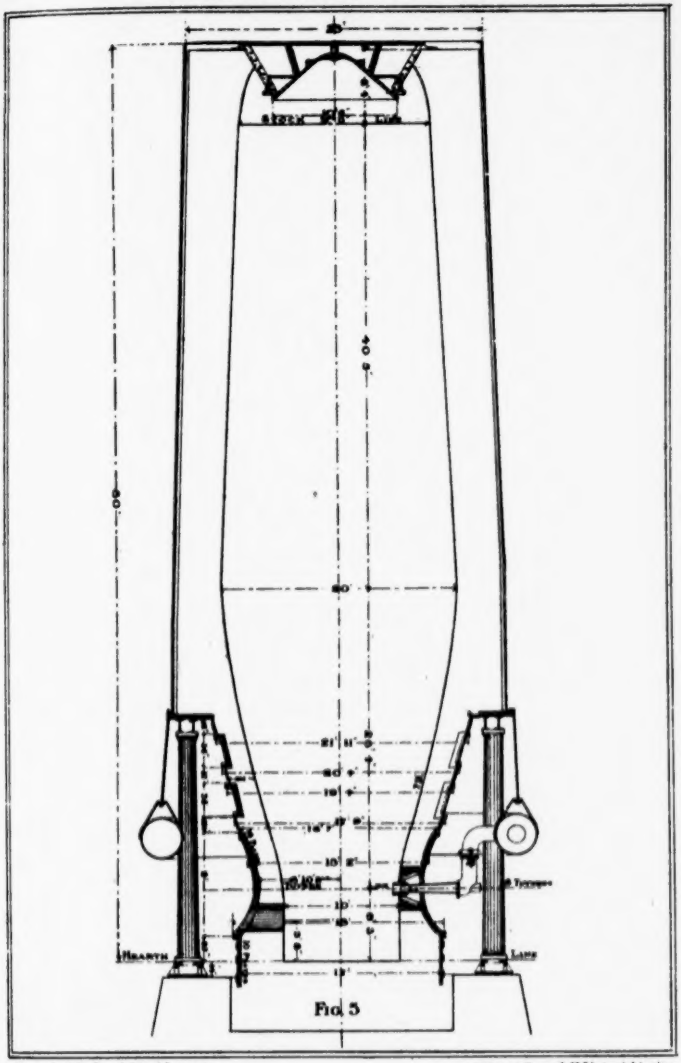

Fig. 5

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Carnegie Steel Co.
to
Cambria Iron Co. } p 1571

PLATE VI.

TO ILLUSTRATE MR. GAYLEY'S PAPER ON "THE DEVELOPMENT OF AMERICAN BLAST FURNACES."

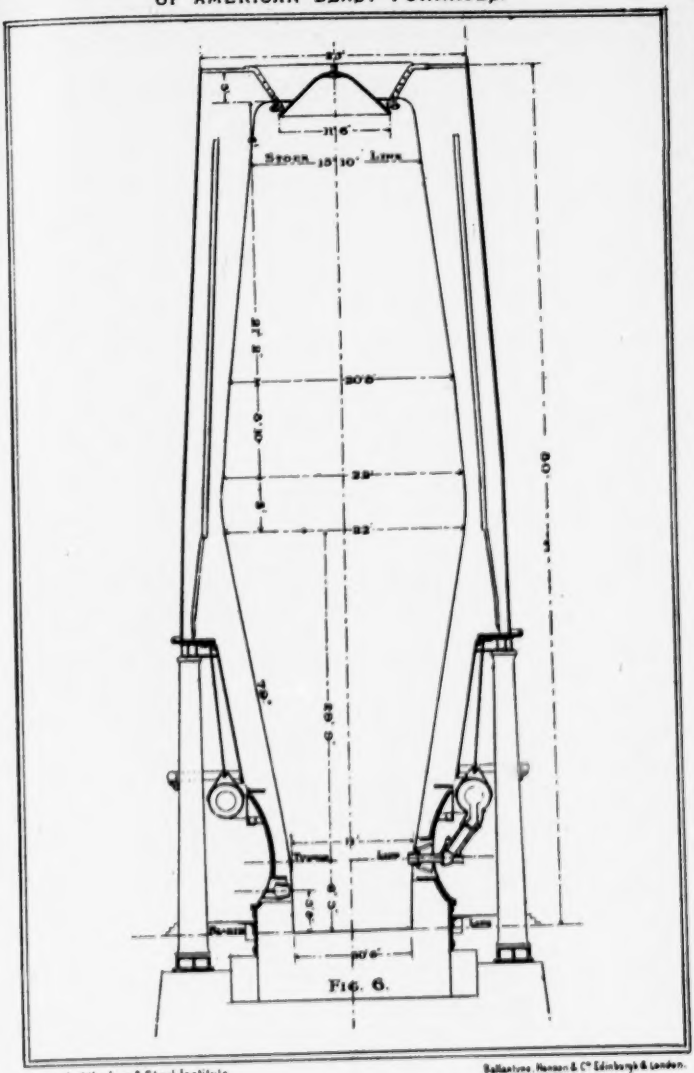

FIG. 6.

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Carnegie Steel Co.
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PLATE VII.

TO ILLUSTRATE MR. GAYLEY'S PAPER ON "THE DEVELOPMENT OF AMERICAN BLAST FURNACES."

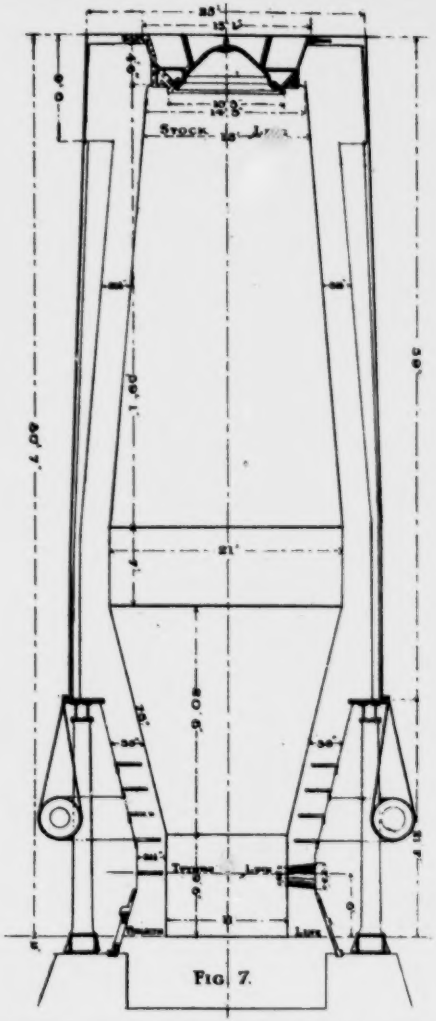

FIG. 7.

Ballantyne, Hanson & Co. Edinburgh & London.

Carnegie Steel Co.
Cambridge
p. 1573

PLATE VIII

TO ILLUSTRATE MR. GAYLEY'S PAPER ON "THE DEVELOPMENT OF AMERICAN BLAST FURNACES."

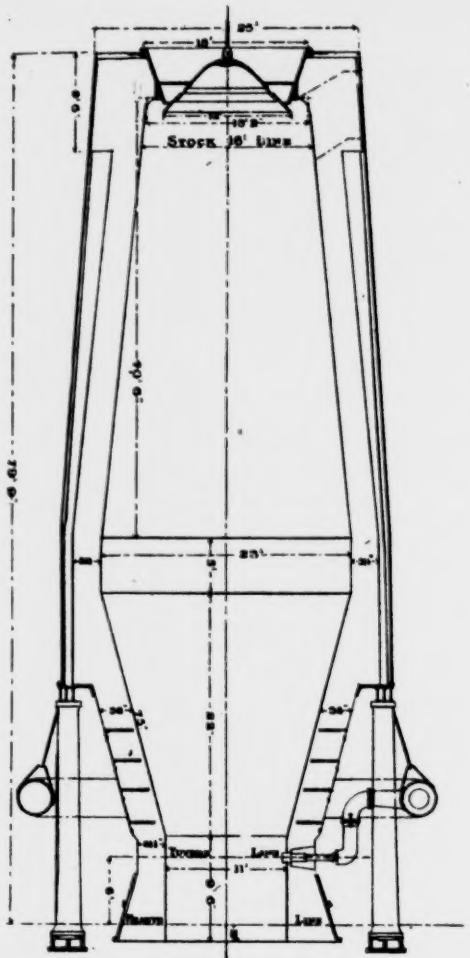

FIG. 8.

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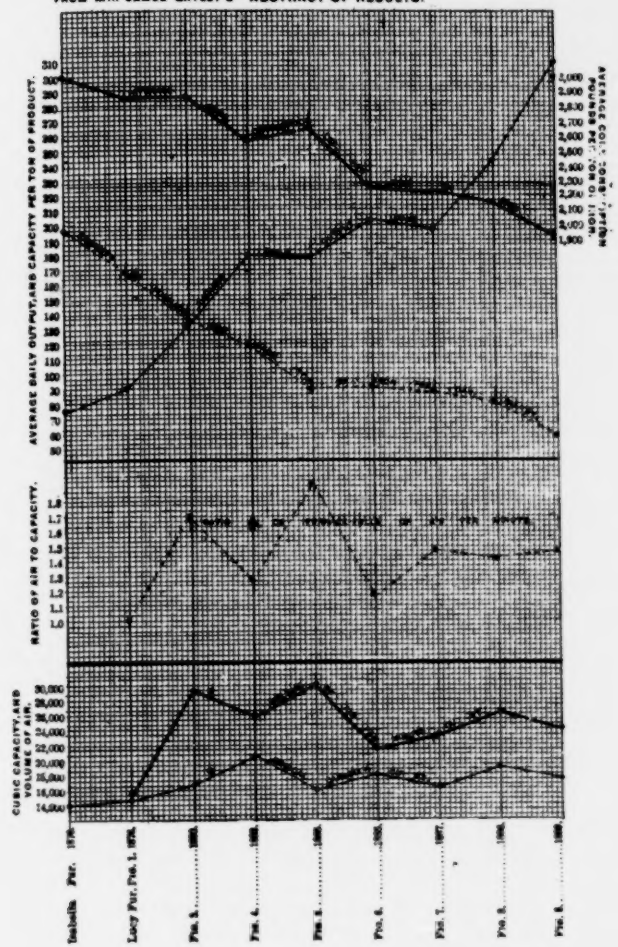
Carnegie Steel Co } 12574

PLATE IX.

TO ILLUSTRATE MR. KENT'S REMARKS ON MR. GAYLEY'S PAPER.

DIAGRAM, SHOWING THE CONDITIONS AND RESULTS OF PIG-IRON PRODUCTION AT THE ISABELLA AND LUCY FURNACES, PITTSBURGH, PA. PLOTTED IN PART FROM MR. JAMES GAYLEY'S "ABSTRACT OF RESULTS."



Ballantyne, Hanson & Co. Edinburgh & London.

Carnegie Steel Co.
Cambria Iron Co. } p. 1575

577 United States Circuit Court of Appeals, Third Circuit.

THE CAMBRIA IRON COMPANY, Appellant,
vs.
THE CARNEGIE STEEL COMPANY, LIMITED, Appellee.

ppeal from the circuit court of the United States for the western district of Pennsylvania.

efore Acheson and Dallas, circuit judges, and Kirkpatrick, district judge.

IRKPATRICK, *District Judge:*

The bill in this case was filed by The Carnegie Steel Company, imited, appellee, as the assignor of U. S. letters patent No. 404,414, anted to William R. Jones, June 4, 1889. It charges infringement and prays for an injunction and account. The defendants by eir answer deny infringement and set up want of patentable velty.

Prior to the hearing the complainant's counsel gave notice that would urge infringement only of the second claim of the patent suit, and it alone is before the court for consideration. It is as llows:

2. "In the art of mixing molten metal to secure uniformity of e same in its constituent parts preparatory to further treatment e process of introducing into a mixing receptacle successive porons of molten metal ununiform in their non-metallic constituents lphur, silicon, &c.), removing portions only of the composite olten contents of the receptacle without entirely emptying or aining the same, and successively replenishing the receptacle ith fresh ununiform additions substantially as and for the purpose scribed."

The patent is for a process method of mixing molten pig metal, d has for its object the procurement of uniformity of the molten etal in its constituent parts preparatory to further treatment. In der to learn the objects sought by Jones and the means employed attain them, reference must be had to the specification and claim, well as the file-wrapper of the patent.

The patent sets out in its title that it is for an improved method of mixing molten pig metal. "It has been found," says the 578 patentee, "that metal tapped from different blast furnaces is apt to vary considerably in chemical composition, particularly in silicon and sulphur, and such lack of uniformity is observable in different portions of the same cast, and even in different rtions of the same pig." There is a tendency of silicon and sulur to segregate, and the consequence "is that the product of the ining process in the converter or otherwise in like manner lacks iformity in these elements, and therefore often causes great innvenience and loss, making it impossible to manufacture all the icles of a single order of homogeneous composition."

The first claim of the patent relates to the art of refining iron di-

rectly from the smelting furnace, but no such limitation is placed upon the second claim, which is now under consideration. The process therein claimed applies to "the art of mixing molten metal." By the use of the more general term "molten metal" it seems to us that the inventor intended to and did broaden his claim so as to include in it the treatment of all molten metals, whether drawn from furnace or cupola. The natural meaning of the words "molten metal" would require that construction, and it appears from the record that it is in accordance not only with the definition of the words furnished by scientific lexicographers and those skilled in the art, but also with the understanding of the inventor himself. In the application for a patent upon the apparatus adapted to carry out the process of the patent in suit, which was filed in the Patent Office on the same day, Jones says: "The main feature of the present invention is, broadly, a covered preliminary receiving vessel for holding and mixing the charges of molten metal, which are supplied thereto either from a blast furnace or cupola." The tendency of silicon and sulphur to segregate t-emselves in molten metal is equally observable in that drawn from cupola and furnace. In both it causes the same inconvenience and loss, rendering the
1579 product of the subsequent refining processes lacking in an uniformity in these elements, and in consequence possessing a variable tensile strength. Neither can the object of the Jones invention be limited to the uniforming molten metal preparatory for its use in the Bessemer converter. The words of the claim and the specification both forbid. In the claim the inventor says he has a process which in the art of mixing molten metal will secure uniformity of the same in its constituent parts preparatory to further treatment. These words are broad enough to include a puddling furnace, an open hearth, or any treatment to which molten metal is adapted in the art and in which it is desirable to have uniformity in its constituent parts. In the specification he declares that his object is to provide means for "rendering the product of steel mills uniform in chemical composition."

Uniformity of product is to be obtained by uniformity of the molten metal required in its manufacture. Particularly but not exclusively would this be true of the steel made by the Bessemer process. All the manufactured articles would be of a single order of homogeneous composition by the elemination of the lack of uniformity in the elements of silicon and sulphur from the molten metal. It does not seem to us that the complainants limit the claim of the patent in suit by the disclaimers which they have filed. In our opinion they do not modify or change the construction of the claim as originally granted. They do not disclaim anything. Their avowed purpose is "to limit the scope of the letters patent to the mixing of molten metal preparatory to further treatment." This we find to be the limit of the patent as originally granted. The disclaimers therefore do not comply with the statutory requirement that the patentee shall give up some material or substantial part of the thing patented of which he was not the original inventor.
1580 If we examine the eliminated parts of the specification we find that they relate, 1, to an example of a way in which the

misture of the molten metal may be made, and which is only one of the obvious varieties of form in which the invention may be practiced, and, 2, the uses to which the mixed metal may be put in the art after the patented process has been completed. Neither of the matters erased affects the process or method of mixing molten pig metal, which was the subject-matter of the patent, nor do they affect anything of which Jones claimed to be the original and first inventor. They do not, therefore, come within the limits laid down by the Supreme Court in Cartridge Co. *vs.* Cartridge Co., 112 U. S., 624, where, speaking by Mr. Justice Blatchford, they say, "The statute expressly limits a disclaimer to a rejection or something before claimed as new." In seeking to find out what was new in the complainant's process and what it was he sought we will be aided by an examination of the file-wrapper. By reference to it, it will appear that the function ascribed by Jones to his intermediate receptacle was one of storage as well as mixing to an uniform standard. In the application as originally filed the "main feature of the invention" was the "method of storing successive charges of molten metal in a receptacle before using it in converters or otherwise," and the invention claimed was the described process "whereby the character of the charges of metal so treated is equalized." The application was rejected by the Patent Office examiner as being completely anticipated by U. S. patent No. 315,587 to Witherow, April 14, 1885, and patent No. 327,425 to Witherow, September 29, 1885, as well as Kirk's Founding of Metals, New York, 1881. Both the Witherow patents claim the combination of a blast furnace with an intermediate storage receptacle between furnace and converter, with a ladle to receive and convey to the converter a proper charge of the molten metal, while Kirk sets out the
1581 function of a large intermediate reservoir to be used in the mixing of molten metal drawn from a cupola. In this finding of the Patent Office the applicant acquiesced. He made certain erasures in the specification and substituted for the objectionable claim one which read as follows: "The process hereinbefore described which consists in running successive charges of molten metal into a covered receptacle provided with a heat-retaining lining, removing from time to time from said receptacle for subsequent treatment a portion only of its molten contents and successively replenishing such receptacle with fresh additions of molten metal for the purpose of equalizing the character of the several charges of metal drawn therefrom, substantially as described." It will be noticed that the new claim is silent as to the storage function of the receptacle, and in the argument filed with the Patent Office Commissioner the applicant declared that the idea of the Witherow patents was "to receive and store the molten metal for the purpose of preventing detention" in practical working, and not to mix the metal gradually, and that in those respects it differed from the Jones application, where the destinctive idea was to have a receptacle capable of hoiding metal in molten condition, into which metal—it may be from several blast furnaces—is run from time to time and from which metal is drawn for treatment in the converter or other-

wise, as required. "This continual pouring into and drawing out of a common receptacle produces such a mixing of the charges as results in an uniform average quality of metal whether treated in the converters or used for casting without such treatment as is very desirable and has been hitherto found to be practically unattainable." Again, the application was rejected at the Patent Office. The Witherow references are withdrawn, no doubt, because the storage function of the reservoir did not necessarily result in the mixing of the metal to the uniform average quality sought by the appli-
1582 cant. The Patent Office, however, again refers to the description of the Kirk method of metal-founding above noted, which states that "the metal is run continuously from the cupola and mixed in the ladle from which it is tapped into small ladles." "The iron is all run out of the cupola as fast as it is melted and is mixed in the large ladle." References are also made to British patents No. 859, Bronan, March 23, 1866; No. 2382, Stewart, May 10, 1883. Again, the specifications and claims of the patent are amended and now made to conform to these set out in the patent in suit.

Quite a transformation has taken place. The storage and reservoiring features have been elim-nated, the mixing has become predominant, and in order that the mixing may be differentiated from that described in the Kirk method it was to be mixing, "whereby its particles are diffused or mingled thoroughly among each other, and the enter charge is practically homogeneous in composition and the product of the further treatment of the metal of a single order of homogeneous composition."

Because the claims of the patent as granted so far differed from those set out in the original application, an affidavit of Jones was annexed, in which he says that "the invention has been found of great practical value in securing uniformity in the product of steel works and these rendering the same more certain in character and more valuable commercially."

In what respect, then, does this new claim differ from the one which had been rejected by the Patent Office examiner and from the Kirk method of founding, to which reference had been made? Only in this: Kirk's method of mixing was that which resulted from pouring the successive casts of one cupola into a reservoir, while the Jones method provided for the mixing not merely of metal taken at one time from the smelting furnace, but of a number of parts taken from different furnaces at different times. In this way, says the patentee, each charge represents an average of a variety of uniform constituent parts, all the charges
1583 of the converter will be substantially uniform, and the product of all will be homogen-ous. Mr. Carnegie testifies on the record that the "soul of the Jones invention is the law of averages, the dealing with successive small portions of metal which may be selected at the blast furnace or the mixer," and again declares its "essence" to be that "the appliances invented by Jones enable successive portions of metal to be combined according to their respective constituents, and this over a number of portions large enough to secure the uniform standard necessary." Should the

metal sent from any furnace be at that time unsuitable for combination with that of other furnaces, it may be rejected by the superintendents. In the Kirk method there was no selection of metals, there was no drawing from many furnaces or cupolas to obtain by the law of average an uniform standard. There was no effort to obtain such a mixture of suitable metal as in combination would produce a standard quality.

These were the objects sought by Jones as we, by the aid of the record and file-wrapper, read the claim and specification of the Jones patent now in suit. What process, then, did Jones devise to attain these ends? It consists of introducing into a mixing receptacle successive portions of ununiform molten metal and removing portions thereof without entirely draining or emptying the same and successively replenishing the receptacle with fresh ununiform additions. The quantity which shall remain in the receptacle is stated to be a "considerable quantity." Beyond this vague description the specification of the patent is silent. We find nothing in the patent which warrants us in determining that the inventor had in mind that the residue to be left in the receptacle should form a dominating pool. The residue, composed of parts of previous charges, mixes with the new portions which are poured in, and thereby the molten metal becomes practically uniform in chemical composition.

This uniformity was to be attained not so much by the pour-
1584 ing into the reservoir metal obtained at several times from one furnace by a number of parts from different furnaces. The stipulation entered into between counsel shows the manner in which the defendants use what is alleged to be the infringing device. It is as follows:

"That the defendant in this case has used the mixer and *and* other apparatus shown in blue prints, Complainant's Exhibits, Nos. 1 and 2 of defendant's mixer together with blast furnaces at Johnstown Pa. since date prior to the commencement of this suit and at various times since that date in the manner following that is to say, the molten pig metal has been tapped from the several blast furnaces, four or five in number and poured into the mixer which has an actual capacity of about two hundred and eighty tons, additions to this molten metal from the blast furnaces being made from time to time to the mixer in quantities of about fifteen tons as it is tapped from the blast furnaces; and that the molten metal in the mixer has been discharged by tapping the mixer from time to time, and as required for charging the Bessemer converters, into ladles having a capacity of about fifteen to eighteen tons each; the charges withdrawn being from about eleven to twelve tons each; that the amount of molten metal in said mixture varies from nothing to its full capacity depending on the supply and demand, the supply being generally sufficient to keep the mixer more than half full of molten metal, which metal remains molten therein that the molten contents of the mixer are drawn off from time to time as required for the converters, the converter charges being from eleven to twelve tons each as above stated; the metal being charged into the converters in a molten condition and sometimes a smaller portion being

withdrawn from the mixer and the remainder of the molten metal for the charge being run into the ladle containing the mixer metal from cupolas forming part of the converter plant, the combined charge of mixer metal and cupola metal being introduced into the converter and refined in the usual manner."

The record shows that the defendant's reservoir or accumulating ladle complained of is the same in principle as one which has been in use at the Cambria works ever since Bessemer steel was first manufactured there, with only this difference, that at first it was used at cupola, now at furnace. The primary object has always been to permit the *ow*rk of Bessemerizing to proceed without interruption to furnish a receptacle for the molten iron of the cupola or furnace when it was most advantageous to tap the same, and thereby avoid a too early tapping, as well as the necessity of being obliged to hold too long. It is stipulated that the amount of molten metal ordinarily kept in the reservoir is more than one-half its capacity, but that it varies from nothing to its full capacity, depending on the supply and demand. 1585 Doubtless under the ordinary conditions there is a mixing of the molten metal when the partially fil-ed vessel is replenished, but it is only such mixing as is incidental to the pouring together of mix*i*ble liquids under the well-known principle of diffusion. As we have said, the Jones patent was not for the storage or reservoiring of metal drawn either from furnace or cupola nor the mixing incidental thereto. The patentee had acquiesced in the finding of the Patent Office examiner that as to these matters he was anticipated by the Witheron patents and Kirk's publication. If the defendant's reservoir carries with it, by well-known natural laws, incidental mixing, it cannot be regarded as an infringement of the patent in suit unless, in addition to its function as a reservoir, it has in combination some additional element set out in complainant's process. If it be urged that the defendants by drawing from several furnaces the molten metal required to replenish their reservoir thereby obtain the average of uniformity sought by complainant's process, the answer is that in this respect the complainant's patent is anticipated by the British patent to Deighton, No. 3672, May 7, 1874, whose claim of invention was the placing of a vessel so as to "receive the molten metal tapped from two or more blast furnaces to get a better average of metal which will be more suitable for making Bessemer steel or metal of uniform quality."

For these reasons we are of the opinion that the defendant's device does not infringe the second claim of the patent in suit.

The decree of the circuit court is reversed and the case is remanded to that court with directions to dismiss the bill of complaint.

1586 In the United States Circuit Court of Appeals for the Third Circuit, March Term, 1899.

THE CAMBRIA IRON COMPANY, Appellant,
vs.
THE CARNEGIE STEEL COMPANY, LIMITED, Appellee. } No. 14.

Appeal from the circuit court of the United States for the western district of Pennsylvania.

This cause came on to be heard on the transcript of record from the circuit court of the United States for the western district of Pennsylvania and was argued by counsel.

On consideration whereof it is now here ordered, adjudged, and decreed by this court that the decree of the said circuit court in this cause be, and the same is hereby, reversed with costs.

And it is further ordered that this cause be remanded to the said circuit court, with directions to dismiss the bill of complaint.

GEO. M. DALLAS, *Cir. Judge.*

Philadelphia, August 24, 1899.

1587 UNITED STATES OF AMERICA, *ss:*

I, William H. Merrick, clerk of the United States circuit court o appeals for the third circuit, do hereby certify the foregoing pages, from one to fifteen hundred and eighty-seven, inclusive, to contain a full, true, complete, and faithful copy of the original transcript of record in the case of The Cambria Iron Company, as appellant, *vs.* The Carnegie Steel Company, Limited, as appellee, on file and now remaining among the records of said court in my office.

In testimony whereof I have hereunto subscribed my name and affixed the seal of the said court, at Philadelphia, this thirtieth day of September, in the year of our Lord one thousand eight hundred and ninety-nine, and of the Independence of the United States the one hundred and twenty-fourth.

Seal United States Circuit Court of Appeals, Third Circuit.

WM. H. MERRICK,
Clerk U. S. Circuit Court of Appeals, Third Circuit.

1588 UNITED STATES OF AMERICA, *ss:*

The President of the United States of America to the honorable the judges of the United States circuit court of appeals for the third circuit, Greeting:

[Seal of the Supreme Court of the United States.]

Being informed that there is now pending before you a suit in which The Cambria Iron Company is appellant and The Carnegie Steel Company, Limited, is appellee, which suit was removed into

the said circuit court of appeals by virtue of an appeal from the circuit court of the United States for the western district of Pennsylvania, and we, being willing for certain reasons that the said cause and the record and proceedings therein should be certified by the said circuit court of appeals and removed into the
1589 Supreme Court of the United States, do hereby command you that you send without delay to the said Supreme Court, as aforesaid, the record and proceedings in said cause, so that the said Supreme Court may act thereon as of right and according to law ought to be done.

Witness the Honorable Melville W. Fuller, Chief Justice of the United States, the twenty-first day of November, in the year of our Lord one thousand eight hundred and ninety-nine.

JAMES H. McKENNEY,
Clerk of the Supreme Court of the United States.

1590 [Endorsed:] Supreme Court of the United States. No. 427. October term, 1899. The Carnegie Steel Company, Limited, *vs.* The Cambria Iron Company. Writ of certiorari.

1591 In the United States Circuit Court of Appeals for the Third Circuit.

THE CAMBRIA IRON COMPANY, Appellant,
vs.
THE CARNEGIE STEEL COMPANY, LIMITED, Appellee.

Stipulation.

It is hereby stipulated by and between the attorneys of record for the respective parties in the above-entitled cause that the certified transcript of the record of said cause filed in the clerk's office of the Supreme Court of the United States, at No. 427, October term, 1899, with the petition for a writ of certiorari herein, may be considered and received as the transcript of the record on the return of the writ of certiorari granted by the Supreme Court of the United States on the 20th day of November, 1899.

Nov. 22d, 1899.

PHILANDER C. KNOX,
For Carnegie Steel Co., Limited.
JAMES I. KAY,
For Cambria Iron Co.

1592 UNITED STATES OF AMERICA, *sct:*

I, William H. Merrick, clerk of the United States circuit court of appeals for the third circuit, by virtue of the foregoing writ of certiorari and in obedience thereto, do hereby certify to the Supreme Court of the United States the consent of the counsel for the respective parties thereto annexed as my return to the said writ.

In testimony whereof I have hereunto subscribed my name and affixed the seal of the said court, at Philadelphia, this 27th day of November, in the year of our Lord one thousand eight hundred and ninety-nine, and of the Independence of the United States the one hundred and twenty-fourth.

Seal United States Circuit Court of Appeals, Third Circuit.

WM. H. MERRICK,
Clerk U. S. Circuit Court of Appeals, Third Circuit.

1593 [Endorsed:] File No., 17,541. Supreme Court U. S., October term, 1899. Term No., 427. The Carnegie Steel Company (Limited), petitioners, *vs.* The Cambria Iron Company. Writ of certiorari and return. Filed Nov. 28, 1899.

Endorsed on cover: File No., 17,541. U. S. circuit court of appeals, 3d circuit. Term No., 427. The Carnegie Steel Company, Limited, petitioner, *vs.* The Cambria Iron Company. Filed October 18th, 1899.